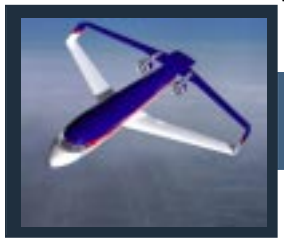
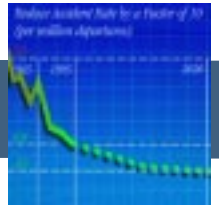
Aeronautics Technology FY 2003 Accomplishments

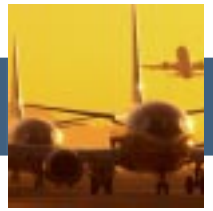
Theme Objectives





Protect Air Travelers and the Public

Protect the Environment



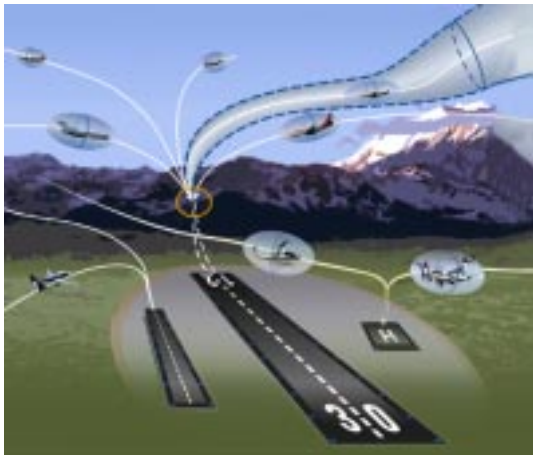
Increase Mobility

Protect the Nation

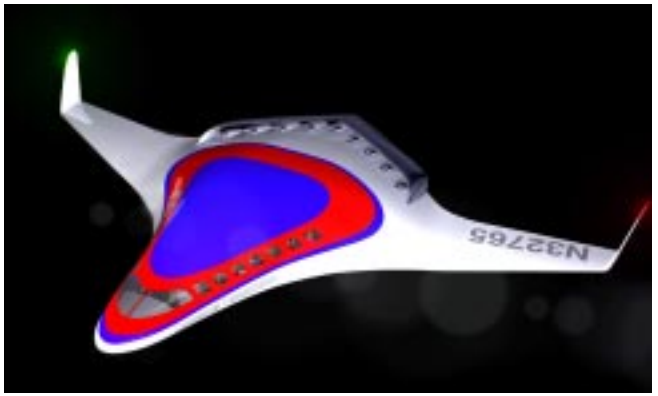
Explore New Aeronautical Missions

Programs

Aviation Safety & Security



Airspace Systems



Vehicle Systems

Aeronautics Technology
Programs & Projects

Aviation Safety & Security

- Vehicle Safety Technology (VST)
  - Accident Mitigation (AM)
  - Single Aircraft Accident Prevention (SAAP)
  - Synthetic Vision Systems (SVS)
- Systems Safety Technology (SST)
  - System-Wide Accident Prevention (SWAP)
  - Aviation System Monitoring and Modeling (ASMM)
- Weather Safety Technology (WST)
  - Aircraft Icing (AI)
  - Weather Accident Prevention (WxAP)

Airspace Systems

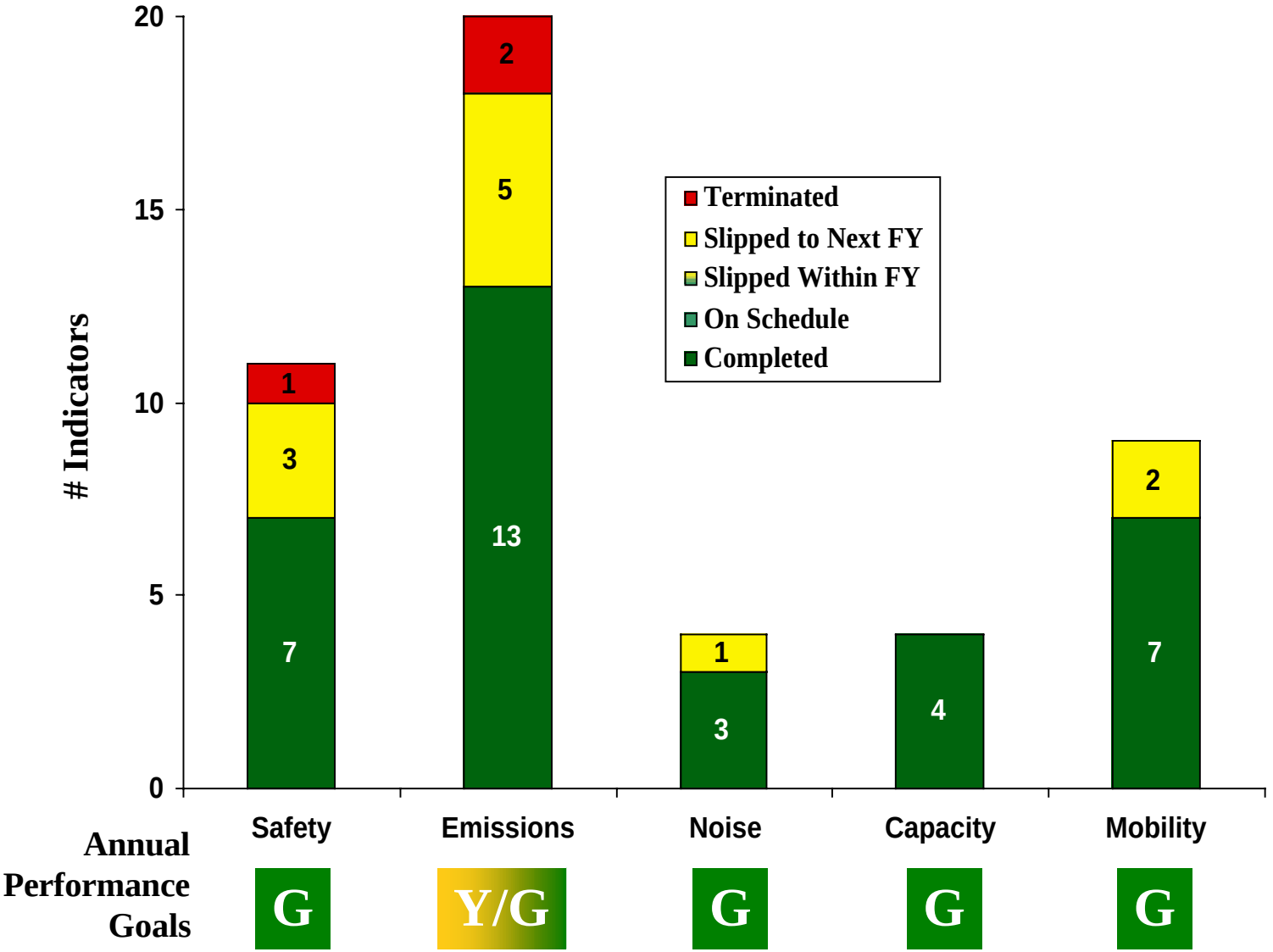
- Advanced Air Transportation Technology (AATT)
- Virtual Airspace Modeling & Simulation (VAMS)
- Small Aircraft Transportation System (SATS)
- Airspace Operations Systems (AOS)

Vehicle Systems

- Breakthrough Vehicle Technology (BVT)
- Advanced Vehicle Concepts (AVC)
- Twenty-First Century Aircraft Technology (TCAT)
- Ultra-Efficient Engine Technology (UEET)
- Propulsion & Power (P&P)
- Flight Research (FR)
- Quiet Aircraft Technology (QAT)

FY 2003 End-of-Year Performance

Aeronautics Technology



FY 2003 Performance Indicators
(Safety)

G

APG 3R1: Demonstrate progress in maturing, through flight tests and/or simulations, the critical technologies that will be necessary to meet the aviation safety objective. These tests and simulations are critical steps in the development of a suite of technologies that when completely developed and implemented by the customer, will provide a minimum of 50 percent reduction in fatal accident rate.

GPRA	PMAS	Projected	Status	Performance Indicator
3R1a	AvSP01	3/30/03	Complete	Demonstrate fast-time simulation of system-wide risks (ASMM)
3R1b	AvSP02	3/30/03	Complete	Model high error probability contexts and solutions (SWAP)
3R1c	AvSP03	2/28/03	Complete	Provide new software certification procedures (SAAP)
-->3R1d	AvSP04	2/28/03	Complete	Demonstration flight critical system validation methods (SAAP)
-->3R1f	**AvSP06**	**3/30/03**	**Slip 6/30/04**	**Complete initial flight evaluation of synthetic vision concepts (SVS)**
-->3R1e	AvSP05	6/30/03	Complete	Demonstrate a smart icing system that will sense the presence of ice accretion on the aircraft, automatically active and manage the ice protection systems, and provide the pilot with feedback including the effect on measured aircraft performance, stability, and control (AI)
-->3R1g	**AvSP07**	**6/30/03**	**Slip 6/30/04**	**Complete initial evaluation of a next-generation cockpit weather information and digital datalink technologies (WxAP)**
3R1i	AVC01	6/30/03	Complete	Initiate intelligent flight control generation I flight test
3R1h	P&P01	9/30/03	Complete	Validate life prediction methodology for critical powder metallurgy super-alloy engine components (nickel-based turbine disk) to enhance aircraft safety
-->3R1j	**AVC02**	**9/30/03**	**Slip 6/30/04**	**Conduct flight testing of the research flight computing system which includes intelligent flight control and propulsion control**
3R1k	**BVT10**	**9/30/03**	**Terminated**	**Develop a transient disturbances recovery strategy for implementation in the SPIDER architecture**

FY 2003 Performance Indicators
(Emissions)

G

APG 3R2: Complete combustor sector test for concepts capable of achieving the 70% NO_x goal by 2007 and select the most promising approaches leading to full annular rig testing for large and regional jet engine applications. Complete an Interim Technology Assessment of the aggregate potential benefits from the engine and airframe technologies to reduce emissions. The results from this analysis will provide a benchmark for measuring overall progress, and guide future investment decisions.

GPRA	PMAS	Projected	Status	Performance Indicator
3R2g	UEET11	12/30/02	Completed	Develop a CMC turbine vane
3R2r	BVT03	12/30/02	Completed	Conduct testing of Stingray vehicle (morphing)
3R2n	**UEET14**	**9/30/03**	**Slip 6/30/04**	**Complete initial high reynolds number validation in wind tunnel of PAI method**
3R2m	UEET13	3/30/03	Completed	Complete evaluation of active flow control concepts for PAI
3R2p	**TCAT03**	**6/30/03**	**Slip 1/31/04**	**Complete flutter risk assessment of high speed slotted wing**
3R2d	BVT02	6/30/03	Completed	Demonstrate adaptive drag reduction techniques
3R2a	BVT01	8/30/03	Completed	Demonstrate the fabrication of carbon nanotubes laminates
3R2o	TCAT02	9/30/03	Completed	Complete evaluation of estimated technology benefits on future vehicle concepts
3R2b	**AVC03**	**9/30/03**	**Slip 8/30/04**	**Demonstrate advanced aeroelastic wing twist (flexible wing) on an F-18 to determine available roll power**
3R2c	FR02	9/30/03	Completed	Complete laminar flow experiment on F-15 testbed
3R2e	P&P02	9/30/03	Completed	Engine test a coated polymer matrix composite inlet guide vane
3R2f	**UEET16**	**9/30/03**	**Slip 9/30/04**	**Simulate a benchmark combustion experiment with a liquid spray injector**
3R2h	UEET12	9/30/03	Completed	Demonstrate a CMC complex part in rig test
3R2i	**UEET03**	**9/30/03**	**NRC/no downselect**	**Downselect large engine contractor for full annular combustor testing**
3R2j	UEET04	9/30/03	Completed	Downselect a regional engine contractor for full annular combustor testing
-->3R2k	UEET05	9/30/03	Completed	Complete sector evaluations of 70% LTO NOx configurations
-->3R2l	UEET17	9/30/03	Completed	Complete an Interim technology benefits assessment
3R2q	**TCAT04**	**9/30/03**	**Slip 9/30/05**	**Validate nonlinear structural analysis tools**
3R2s	**P&P03**	**9/30/03**	**Terminated**	**Complete oil free FJX-2 core testing**
3R2t	**FR01**	**9/30/03**	**MIB**	**Demonstrate a prototype electric powered UAV capable of sustaining 14 hours of operation above an altitude of 50,000 feet**

FY 2003 Performance Indicators

(Noise/Capacity)

G

APG 3R3: Complete development of initial physics-based prediction models to guide the development potential noise reduction technology concepts. Complete an interim technology assessment of the potential benefits for these concepts to reduce noise emissions. The results from this analysis will provide a benchmark for measuring overall progress, and guide future investment decisions.

GPRA	PMAS	Projected	Status	Performance Indicator
3R3a	QAT01	9/30/03	Completed	Three-dimensional noise propagation code for engine nacelles
-->3R3b/e	QAT02	9/30/03	Completed	Develop initial physics-based noise prediction models
3R3c	**QAT03**	**9/30/03**	**Slip 3/30/04**	**Quantify potential benefits of advanced noise abatement profiles and procedures at key airports.**
-->3R3d	QAT04	9/30/03	Completed	Complete an interim technology benefits assessment

G

APG 3R4: Complete development, initial functionality and evaluate human factors for at least one decision support tool to enable achievement of the planned progress towards the goal of doubling the capacity of the National Airspace System in 10 years. Complete the initial build of a toolbox of state-of-the-art airspace models to enable the planned progress towards the 2022 Objective.

GPRA	PMAS	Projected	Status	Performance Indicator
-->3R4a	AATT01	2/15/03	Completed	Develop, demonstrate initial functionality, and evaluate human factors for a decision support tool for complex airspace.
3R4b	AATT02	9/30/03	Completed	Develop, demonstrate initial functionality, and evaluate human factors for active terminal-area decision support tool.
-->3R4c	VAMS01	12/30/02	Completed	Complete initial build of State-of-the-art airspace model toolbox
3R4d	AOS01	6/30/03	Completed	Provide strategies for improving training and procedures to reduce misunderstandings between pilots and air traffic controllers

FY 2003 Performance Indicators
(Mobility)

Y/G

APG 3R5: Select candidate technologies for experimental flight evaluation based on their impact on mobility. Mobility metrics will be measured by accessibility, doorstep-to-destination transit time, system and user costs, and related trip reliability and safety metrics. These flight experiments will evaluate individually, at the sub-system level, the impact of selected technologies on lowering required landing minimums and increasing the volume of operations at non-towered landing facilities in non-radar airspace during instrument meteorological conditions.

GPRA	PMAS	Projected	Status	Performance Indicator
-->3R5a	SATS01	2/20/03	Completed	Select flight experiment technologies
3R5b	SATS02	12/31/02	Completed	Complete lower landing minimum flight experiment
3R5c	**SATS03**	**12/31/02**	**Slip 12/30/03**	**Complete higher volume operations flight experiment**
3R5d	SATS04	5/31/03	Completed	Evaluate integrated single-crew flight deck technologies
3R5e	SATS05	10/30/02	Completed	Demonstrate increased mobility without compromising enroute capacity
3R5f	BVT01	8/30/03	Completed	Demonstrate the fabrication of carbon nanotubes laminates
3R5g	**TCAT04**	**9/30/03**	**Slip 9/30/05**	**Validate nonlinear structural analysis tools**
3R5h	BVT04	7/30/03	Completed	Publish abrupt wing stall validated figures of merit and design guidelines
3R5i	BVT03	12/30/02	Completed	Conduct Stingray vehicle testing

Aviation Safety and Security Program

Fast-time Simulation of System-wide Risks Demonstration

POC: Irv Statler, ARC

September 2003

Relevant Milestone: Fast-time Simulation of System-wide Risks, (AvSP LII Milestone, 4th Quarter FY03)

Shown: The use of fast-time simulation to compare controller workload and traffic performance using miles-in-trail metering versus time-based metering has been validated by comparisons with PDARS analysis of corresponding radar track data and on-site controller performance data. APMS provided qualitative confirmation of corresponding aircraft flight operations.

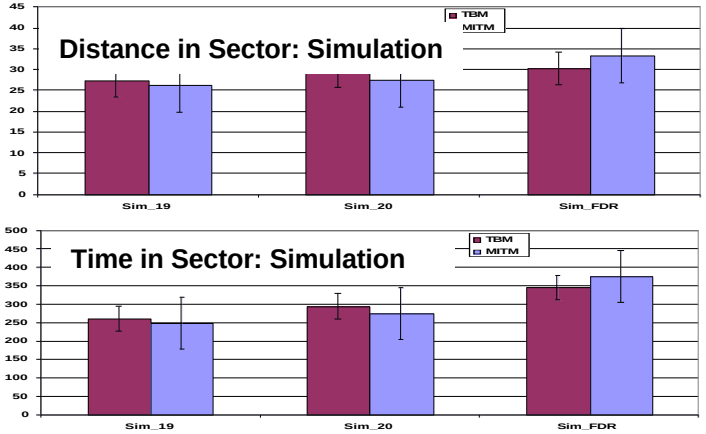
Accomplishment / Relation to Milestone and ETO: Simulation, explicitly incorporating performance models of the human operators, has been used to compare system effects of time-based metering (TBM) versus miles-in-trail metering (MITM) of typical traffic at LAX. The scenario was traffic on approach to runways 24L/R and 25L/R at LAX, from ZLA center sectors 19 and 20 into SCT sector FEEDER. Sector controllers of FEEDER and ZLA 19 and 20 were modeled to predict controller performance and evaluate workload. Based on PDARS data, flight schedules of LAX arrivals and other flights entering ZLA 19 and 20 and SCT FEEDER were simulated. We validated the simulation using a larger sample of flights from PDARS data. APMS was used on flight-recorded data to evaluate the effects on aircraft performance, flying technique, navigation workload, and operational outcomes. We have validated the use of fast-time simulation to produce causal predictions of performance as an element in support of proactive management of system-wide risk when introducing new technologies or procedures. We can say, with at least 98.2% confidence, that there is no statistically significant difference between simulated and actual data. All differences are within one standard deviation of the respective distributions.

Future Plans: Link fast-time simulation to automated risk-assessment tools and validate the risk projections and the causal factors of anomalous outcomes using analyzed data from PDARS and APMS.

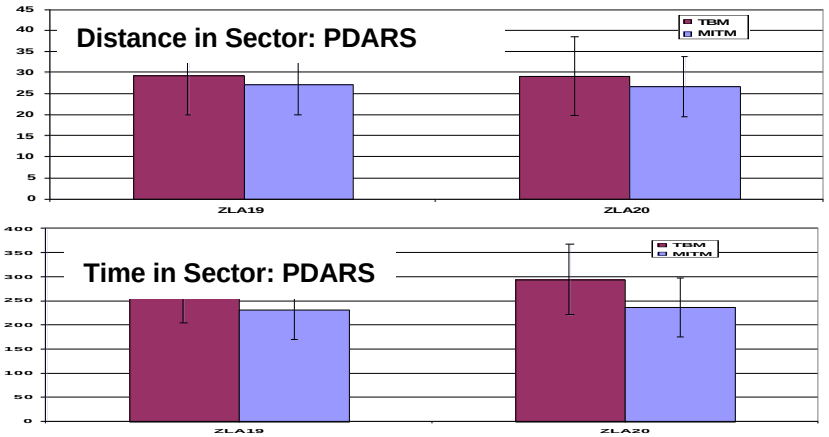
Aviation Safety and Security Program

Aeronautics Technology

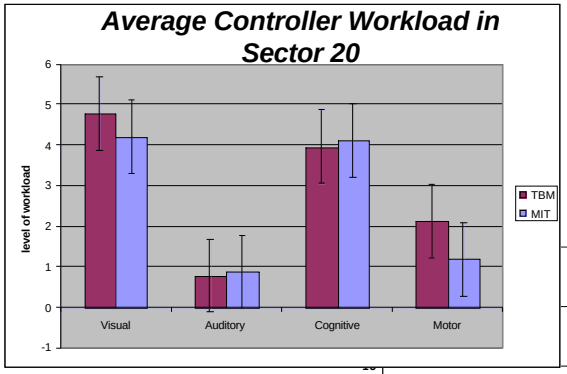
Simulated Traffic Performance

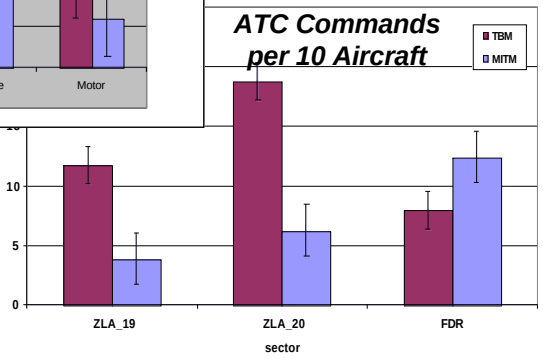


Traffic Data Analysis -- PDARS



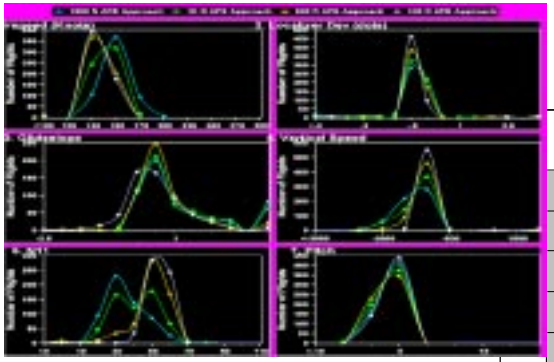
Simulated Human Performance



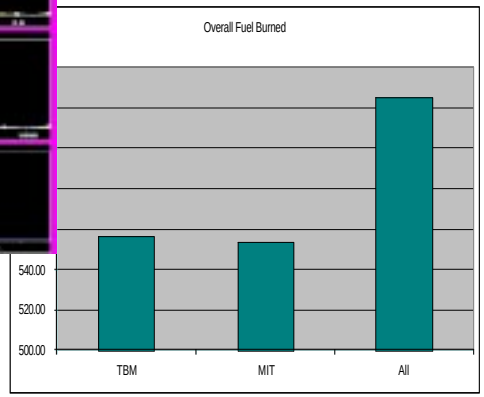


Flight Data Analysis -- APMS

Performance Parameters



Operational Consequences



3AvSP01

Human Performance Modeling Element

POC: Dr. David Foyle, ARC

September 2003

Relevant Milestone: Model High Error Probability Contexts and Solutions (MS 2.2 / 3). Evaluation report on computational simulations of commercial pilot performance during approach and landing operations with augmented displays.

Shown: Operational problem investigated; modeling architectures utilized; range of simulation outputs; and the evaluation report detailing these efforts and related findings.

Accomplishments:

- Prepared detailed cognitive task analysis of B757 flight crew procedures, timing, and informational needs during approach and landings with and without the availability of an SVS-type display.
- Conducted part-task, human-in-the-loop simulation study of approach and landing operations in a Boeing-757 class aircraft with and without a panel-mounted SVS display – generating performance, eye-tracking, and questionnaire data across 10 different flight scenarios.
- Developed 5 diverse computational models of flight crew performance during approach and landing operations with and without an SVS display; used each model to perform simulation study of a baseline and a late runway reassignment scenario requiring flight crews to execute a sidestep maneuver to an adjacent parallel runway.
- Held technical workshop with over 60 attendees from NASA, the Army, industry, and academia to describe and clarify the specific modeling approaches used in this effort and to note findings and implications regarding SVS display usage.
- Produced comprehensive evaluation report which provides extended and detailed accounts of each of the workshop presentations

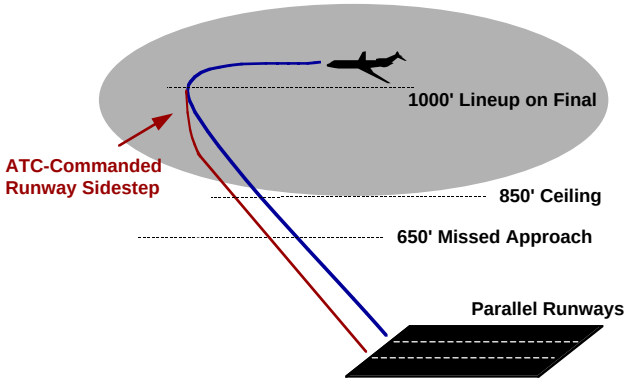
Future Plans: Extend current computational models of nominal SVS usage to investigate off-nominal approach and landing scenarios; missed approach, traffic on runway, display malfunction. Verify robustness and validate model outputs through comparison with independent data set.

Using Cognitive Modeling and Simulation to Investigate Human Performance during Approach and Landing Operations with Augmented Displays

Aeronautics Technology

Scenarios of Interest

* Nominal baseline approach/landing and late runway reassignment (sidestep) with and without a SVS display



Modeling Architectures

ACT-R/PM
University of Illinois
Rice University

Air MIDAS
San Jose State University

A - SA
University of Illinois

D-OMAR
BBN Technologies

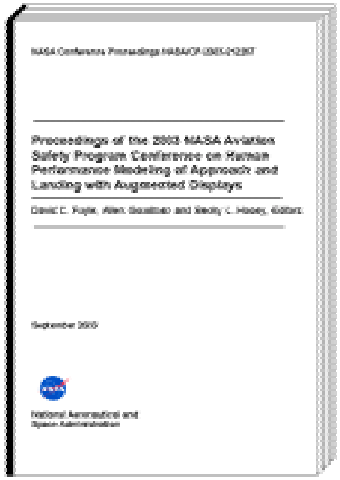
IMPRINT/ACT-R
Micro Analysis & Design
Carnegie Mellon Univ.

Fast-Time Simulation Analyses

* Predictions of pilot performance & workload
* Estimates of attentional demands & SA
* Task execution timelines & mission success rates
* Error vulnerabilities

Workshop & Evaluation Report

* Government/Industry technical workshop conducted (3/03)
* Goodness-of-fit of individual model outputs to empirical data
* Implications regarding information display, pilot attentional allocation & scanning strategies
* Timing issues and error vulnerabilities
* Lessons learned concerning model construction & individual model sensitivity



3AvSP02

Delivery of Automated Verification Tool for Fixed-Structure Neural Networks for Certification of Flight Critical Software

POC: Celeste M. Belcastro, LaRC

Date Completed: March 2003

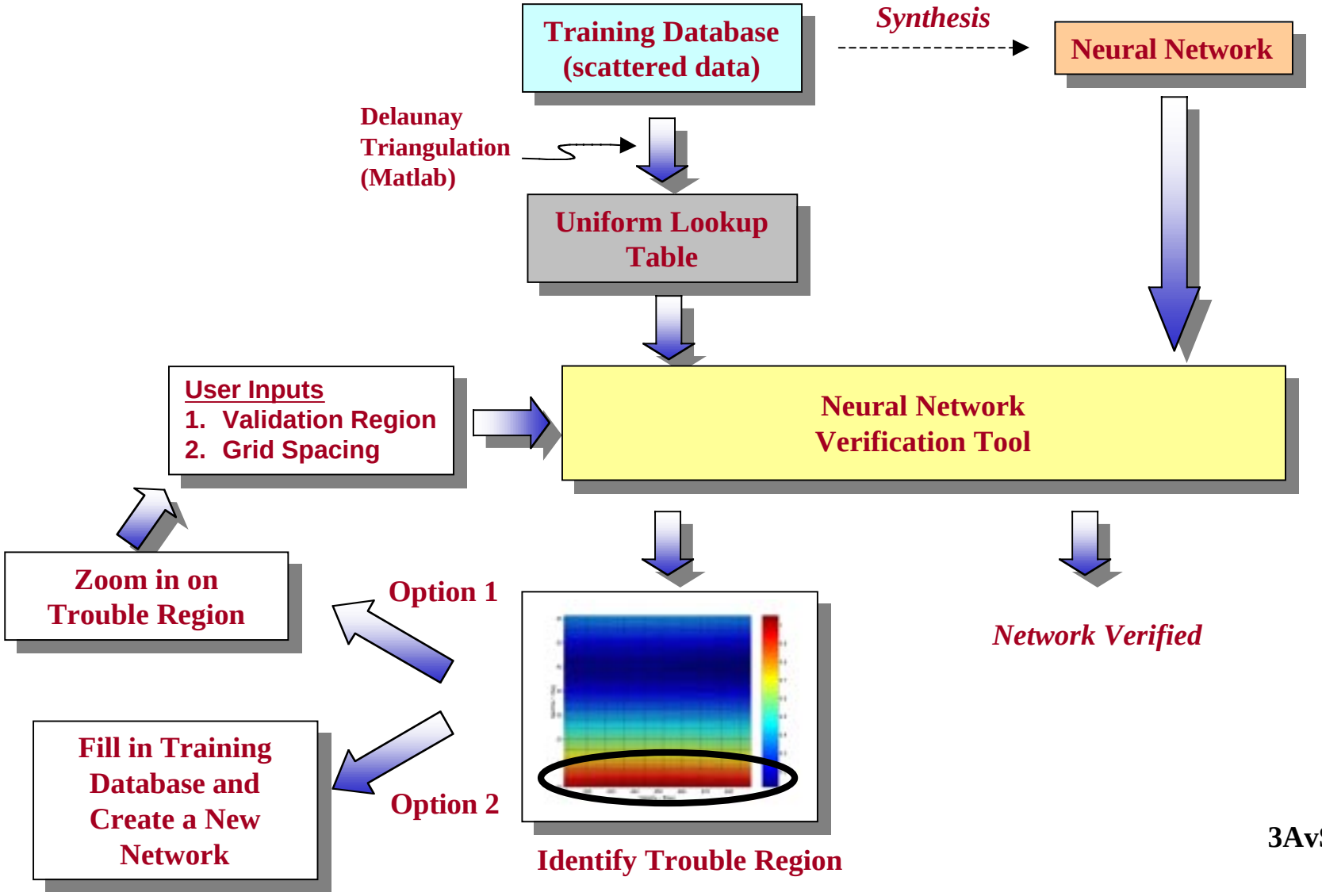
Relevant Milestone: Software (S/W) Certification Procedures: Provide new certification procedures suitable for FAA incorporation into the next revision of DO-178B (SAAP, LII Milestone, April 2003)

Shown: Diagram of the Process for Verification of Fixed-Structure Neural Networks with the Automated Tool

Accomplishment: Final delivery of the Neural Network Verification Software Tool developed by Barron Associates and Goodrich Aerospace under a cooperative agreement with NASA was completed in March 2003. The objective of this activity was to develop tools and methods to enable certification of neural network based software applications. In this particular activity, software tools and methods were developed to support the certification of an advanced fuel measurement system on the Fairchild Dornier 728 regional jet. The methods and tools developed appear to have achieved satisfaction of the requirements specified by DO-178B for use in systems to be certified by the FAA. No specific changes to DO-178B to accommodate neural networks appear to be necessary at this time. Other applications of this tool by Barron Associates include rotor torque anticipation for the next generation Blackhawk fuel controller and reconfigurable control design for F-18 retrofit.

Future Plans: Transfer this technology to other AvSP partners for application. Expand capability of automated tool for additional types of neural networks, as appropriate.

Barron/Goodrich Neural Network Verification Process using Automated Tool



Laboratory Demonstration of Validation Methods to Determine Neutron Particle Effects on Flight Critical Systems

POC: Celeste M. Belcastro, LaRC Date Completed: April 2003

Relevant Milestone: Demonstration of Flight Critical System Validation Methods: Complete development and laboratory demonstration of validation methods for complex and highly integrated flight critical systems (SAAP, LII Milestone, April 2003)

Shown: Quad-Redundant FCC Experiment Conducted at Los Alamos National Laboratory, NM 12/2002

Accomplishment: Experimental validation methods for evaluating the impact of neutron particles on complex and highly integrated flight critical systems were demonstrated in a closed-loop system-level experiment conducted at the LANSCE facility of the Los Alamos National Laboratory in New Mexico on December 12-14, 2002. Single Event Upset (SEU) phenomena caused by neutron particles have been documented at the chip-level since 1979. However, system-level test methods for assessing vulnerability and validating performance in this environment had not been previously developed. In this experiment, an older generation (20 year) digital Flight Control Computer (FCC) interfaced to real time simulation was subjected to neutron particles to investigate system effects. As expected the neutron particles did not upset the older FCC because of the relatively large size of the components within it. However it is anticipated the smaller sized components of newer generation digital computers will be susceptible to neutron particle effects.

Future Plans: The application of these experimental validation methods will be demonstrated in future experiments on newer electronic device technology (1 micron or less feature size) used in a Recoverable Flight Control Computer, and the latest electronic device technology implemented in an integrated modular architecture with independent application partitions. It is expected that SEUs will be observed in these newer computer architectures, as component testing has already revealed this phenomena. The second and third experiments are planned for 2004.

Aviation Safety and Security Program

Aeronautics Technology

LANSCE Neutron Particle Test Facility Los Alamos, NM

Quad-Redundant Flight Control Computer Aligned in Neutron Particle Beam

Aircraft Emulation Computer that was Interfaced to the Quad-Redundant Flight Control Computer (FCC)

Data Collection Computer and Monitor Displays for the Four Commands from each of the Four Processors

Smart Icing System Demonstration

POC: Mary Wadel, PI : Tom Bond & Tom Ratvasky, GRC

June 2003

Relevant Milestone: Smart Icing System (SIS) Ice Management System Demonstration, (AI, LII Milestone, 3rd Quarter FY03)

Shown: SIS Ice Management System (IMS) Concept and demonstration using desktop simulator

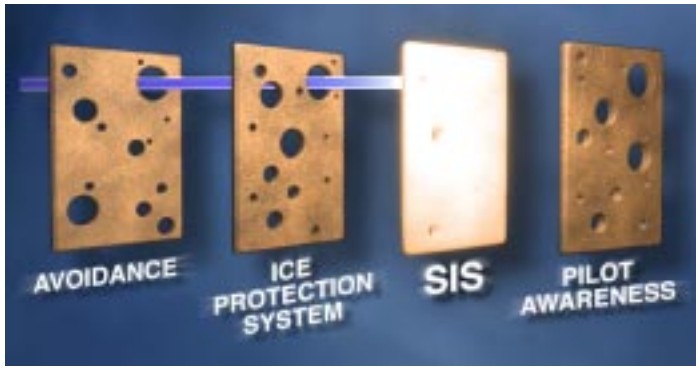
Accomplishment / Relation to Milestone and ETO: The first step in a state-of-the-art advance in ice protection system management, a Smart Icing System, has been demonstrated through simulation using an icing flight test database. The SIS concept is an Ice Management System that, when fully implemented, would sense the presence of ice accretion on an aircraft, automatically activate and manage the ice protection systems, and provide the pilot with feedback including the effect on measured aircraft performance, stability and control. The SIS concept has been integrated into a desktop simulator that includes operational characteristics for ice protection system management - including system operation, aircraft state awareness, and pilot feedback information. The simulator flight response models were validated against the NASA Glenn Icing Research Aircraft flight test data. Flight envelope and autopilot models were researched to determine parameter identification methods to characterize aircraft flight dynamics, aerodynamic state of the vehicle, and flight management systems to automate control responses. The desktop simulator was demonstrated with a sample pilot audience in training scenarios to identify appropriate awareness and action cues for the pilot with a SIS capability. Cognitive engineering evaluations were completed to determine human-centered design and primary flight displays for pilot interface.

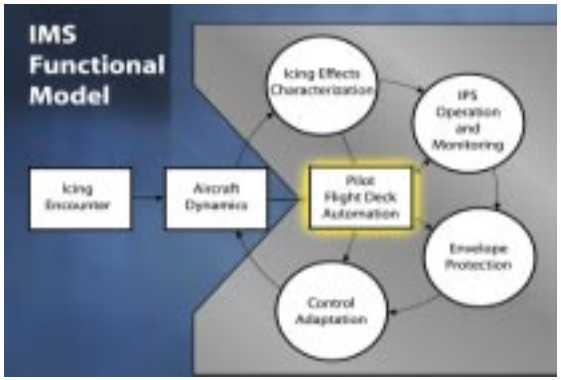
Future Plans: Evaluate alternate parameter ID methods, integrate SIS package into flight-based system, demonstrate in flight

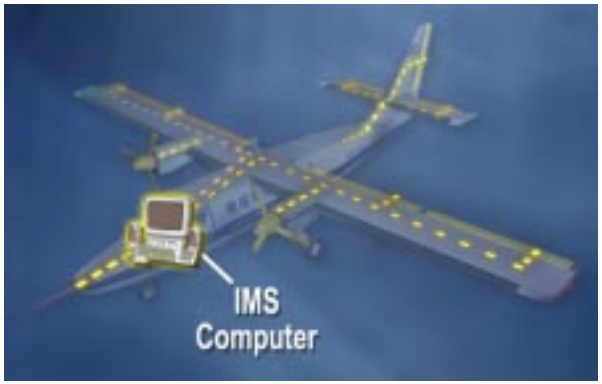
Aviation Safety and Security Program

Aeronautics Technology

Smart Icing System (SIS) adds another layer of safety through the Ice Management System (IMS)







Simulator demonstrated in training scenarios to identify awareness and action cues

Ice Hazard Notification through the Ice Management System

Complete Simulations and Flight Test Evaluations of Safety-Improvement Systems

POC: George B. Finelli, LaRC Completion Date: September 2003

Relevant Milestone: Complete Simulations and Flight Test Evaluations of Safety-Improvement Systems, Level 1 MS# 1-4

Shown: Terrain Portrayal of Head-Down Display testing in C-206, wind tunnel testing and advanced simulation capability for improved pilot training to recover from adverse or upset conditions, and the Honeywell Weather Information Network (WINN) system used in United Airlines In-Service Evaluations.

Accomplishment:

Individual safety-improvement systems and safety enhancements have been evaluated in simulations and flight tests:

- The use of fast-time simulation to compare controller workload and traffic performance using miles-in-trail metering versus time-based metering has been validated by comparisons with Performance Data Analysis and Reporting System (PDARS) analysis of corresponding radar track data and on-site controller performance data. Aviation Performance Measuring System (APMS) provided qualitative confirmation of corresponding aircraft flight operations. Simulations demonstrated the ability to predict the impact of new technologies when introduced into an operating system.
- Developed virtual environment of an aircraft cargo bay and artificial defects such as damaged conduit, corrosion, and cracks for real-time inspection simulation for improved inspection performance and job training by the aircraft maintenance industry.
- Developed cockpit automation training materials endorsed by the University Aviation Association (UAA). Purdue University, one of the largest aviation training departments in the country, plans to integrate cockpit automation coursework into their 4-year curriculum. The UAA endorsement will facilitate implementation of the products into U.S. training schools.
- Completed extensive wind tunnel testing of B757 model, developed enhancements to database and math models for adverse or upset conditions, and incorporated into vehicle simulation. As a result, aircraft flight characteristics that were previously unavailable in upset conditions can be obtained for improved crew training or engineering analysis.

Aviation Safety and Security Program

Aeronautics Technology

Complete Simulations and Flight Test Evaluations of Safety-Improvement Systems

Wind tunnel testing and analysis lead to advanced simulation capability for improved pilot training to recover from adverse or upset conditions

Terrain Portrayal of Head-Down Display testing in C-206 mitigates loss of control risk by providing additional situation awareness

Honeywell Weather Information Network (WINN) system used in UAL In-Service Evaluation demonstrated time savings and turbulence mitigation

Complete Simulations and Flight Test Evaluations of Safety-Improvement Systems

Accomplishment Continued:

• Near-term technology graphical weather displays for transport and General Aviation aircraft were developed and demonstrated in flight using the LaRC 757, ARNAV Cessna 180, and the LaRC B200 King Air. The Honeywell Weather Information Network (WINN) system used in United Air Lines In-Service Evaluations demonstrated time savings and turbulence mitigation. The Rockwell Enhanced Weather Radar system demonstrated the display of uplinked NEXRAD data combined with on-board radar data to provide the pilot with graphical weather information. Commercialized products for better weather information to flight crews have resulted.

• Documented "Best Practices in Crash Modeling and Simulation" as a tool to assist impact modelers. Discussions include details in developing dynamic finite element crash models, model execution, analytical predictions, test-data analysis, filtering procedures, and test-analysis correlation.

• Completed complementary simulation and flight test efforts to evaluate critical terrain portrayal concepts that provide essential data to enable design trades that optimize SVS applications, as well as developed requirements and recommendations to support certification of SVS Head-Down Displays. Results from the experiments demonstrated the efficacy of SVS displays to eliminate Controlled Flight Into Terrain (CFIT) accidents and greatly improve pilot's Situation Awareness (SA). Prior to the terrain portrayal for head-down displays (TP-HDD) combined experiments, the relationship between the realism of the terrain presentation and the resulting enhancements of pilot SA and performance was largely undefined.

Status/Future Plans: A vehicle health management flight demonstration originally planned for FY03, was replanned in 1999 (AvSP CR55) and now is expected to demonstrate feasibility of implementation and operational benefits of health management technologies in FY04. Due to the LaRC 757 safety stand-down, additional planned tests of synthetic vision and weather concepts have been delayed. Alternative aircraft and simulation options will be used to mitigate risk of further delays.

Flight Demonstration of Forward-looking X-band Radar Turbulence Warning System

POC: K. Martzaklis, GRC, Sept 16, 2002

Relevant Milestone: WxAP Level II Milestone, #2 4Q/02; TRL/IRL=6/5; Roll-up to Lvl1 #4 (2Q/03)

Shown:

Radar reflectivity and hazard maps from NCAR post-processing (with *in situ* overlay) of data collected on B-757 ARIES, demonstrating X-band radar detection of hazardous levels of turbulence at ranges greater than 5 km ahead of aircraft and no significant reflectivity indicated on standard weather radar.

Accomplishment/Relation to Milestone:

- Installed research radar system with real-time hazard estimation algorithms on NASA B-757 ARIES and conducted flight experiments to collect low reflectivity radar data and assess overall system performance. The research radar was operated on 20 flights in 2000 through 2002, and a total of 43 radar data files of moderate or greater turbulence encounters were collected.
- Data analysis (using human judgment) indicates excellent performance with probability of detection of severe turbulence (equal to or greater than 0.2 RMS g) with a lead time greater than 30 seconds at 81%, and a nuisance alarm rate at 11%. Reflectivity in several cases was at or slightly lower than 15dBz.

Benefits:

- Improved algorithms for estimation of turbulence were developed and shown to work in real-time in an experimental prototype radar, based on current-generation commercial radar technology. This approach is intended to enable retrofit of current wind shear capable X-band radar systems for transport aircraft to provide substantial improvements in turbulence detection, and to add hazard estimation relevant to the particular class of airframe.
- Radar data collected was compared to “truth” winds and loads measurements as provided by *in situ* algorithms.

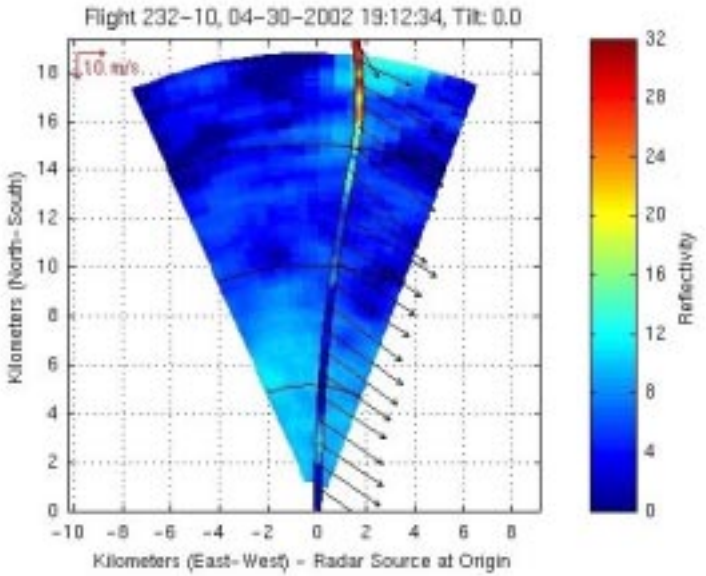
Plans:

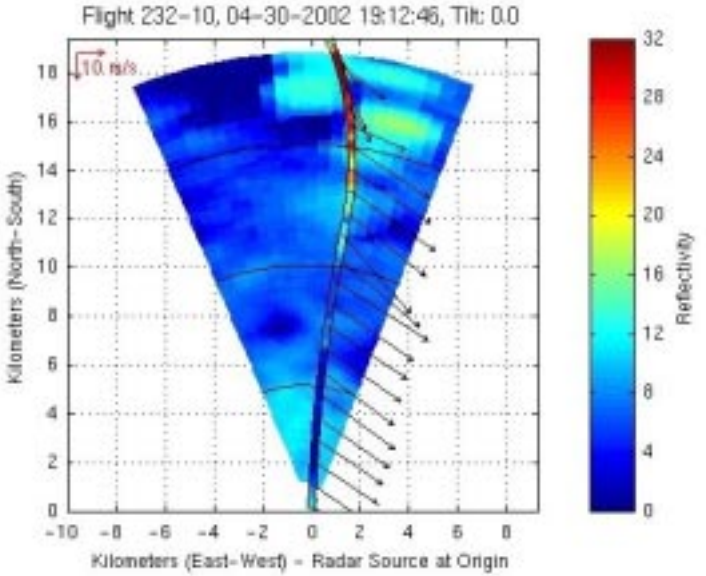
- The experimental turbulence radar system will be further enhanced by the addition of alerting algorithms and cockpit displays to support future TPAWS/WxAP flight deck integration research.
- This data will support validation of convective turbulence atmospheric and radar simulations, and provides a basis for FAA certification of radar systems offering hazardous turbulence prediction and cockpit alerting.

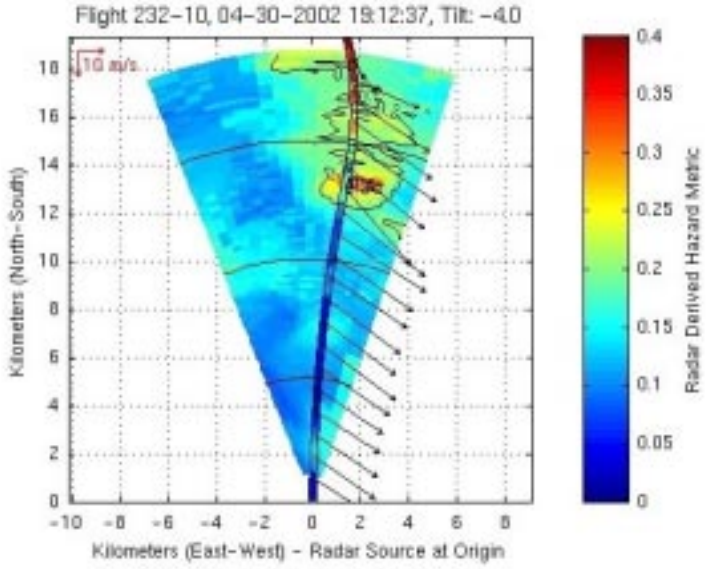
Aviation Safety and Security Program

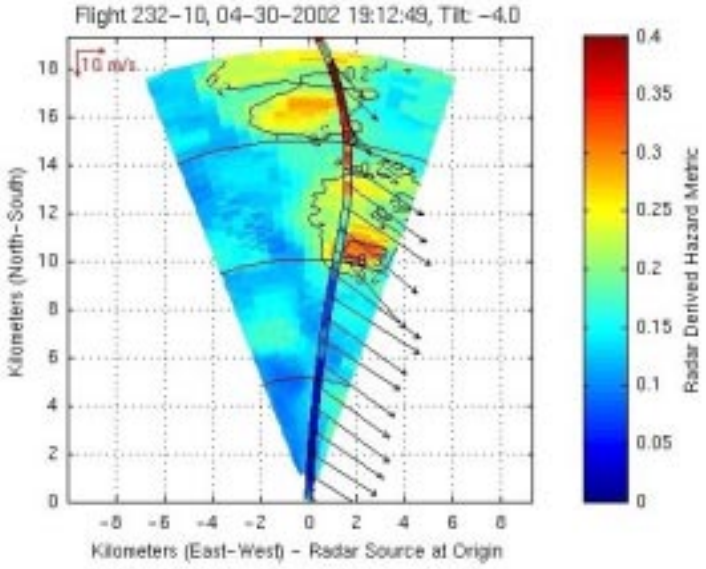
Aeronautics Technology

Radar Data for Event R232-10









Airspace Systems Program

Developing Initial Functionality for Decision Support Tool for Complex Airspace

- Target: 2R4 — To develop a decision support tool (for Air Traffic Management [ATM]) and define concepts for future aviation systems.
- Indicator: Develop, demonstrate initial functionality, and evaluate human factors for active decision support tool for complex airspace.
- Metric: Increased throughput/capacity at airports
- Description of activity (what was done and how): McTMA developers completed and tested the first increments (Multi-Facility Coordination) through simulation exercises, and completed and tested the initial collaboration capabilities of the Collaboration and Metering increment. McTMA has been deployed to the New York TCC and Cleveland ARTCC and is awaiting installation at the Washington ARTCC and Boston Center. Initial prototype software was released, installed, and is running ate ARR simulation laboratory.
- Date(s) of tests and also date for completion of data analysis: Completed 12/31/02
  - Results: Simulation results indicated: (1) metering for Philadelphia appears viable in Boston ARTCC, (2) more delay absorption capacity in Boston ARTCC than New York or Washington ARTCCs, (3) McTMA's internal departure scheduling is important, and (4) significant metering issues in Boston ARTCC.
  - Testing limitations: None.
  - Availability of documentation (who / where): Tom Davis, ARC/AFA
- Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology:
  - Multi-Center will enable the more efficient management of arrival flows using highly accurate time-based metering across multiple Centers.

Multi-Center Traffic Management Advisor (McTMA)

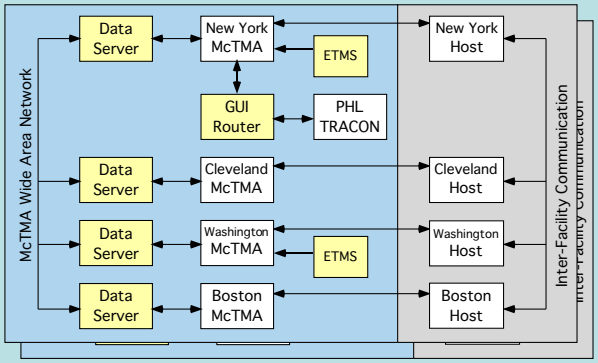
Completed Milestone: Develop, demonstrate initial functionality, and evaluate human factors for active decision support tool for complex airspace.

The Problem:
Interdependent traffic flows through congested airspace, characterized by reactive flow management and delays which quickly propagate upstream and affect multiple Centers.

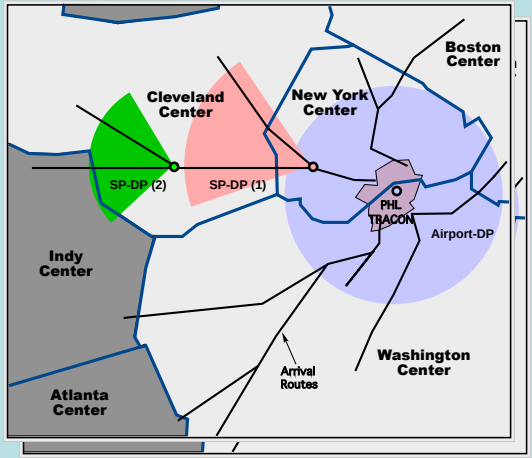
Methods:
Ongoing system development with facility controllers and traffic managers involved in operational concept formulation, simulation, and field evaluation.

Solutions:

- Creation of a modular and expandable data server and system architecture.



- Creation of a scheduler to enable a more flexible form of time-based metering to efficiently and fairly allocate delay across multiple facilities.



AATT Develops Initial Functionality for Terminal Area Decision Support Tool (EDP)

- Revolutionize Aviation, Airspace Systems, AATT
- Target: 3R4 — To develop a decision support tool (for Air Traffic Management [ATM]) and define concepts for future aviation systems.
- Indicator: Develop, demonstrate initial functionality, and evaluate human factors for active terminal area decision support tool.
- Metric: Increased throughput/capacity at airports
- Description of activity : Expedite Departure Path (EDP) was tested in high fidelity simulation to demonstrate tool algorithm functionality at a TRL 4 level. EDP trajectories employed new algorithms that included speed, route, and altitude degrees of freedom, driven by adaptation, and allowed accelerating climb.
- Date(s) of tests and also date for completion of data analysis: Q3&4, FY03. Completed. As planned, concludes AATT Project work with EDP
- Results:A fast-time simulation of air traffic was used to assess EDP's benefits. For the cost assessment, a cost assessment model calibrated with Free Flight Phase 1 TMA cost data was used. The results indicate that under all scenarios, the benefits from implementing EDP would significantly exceed the costs. Of the EDP functions, the EDP unrestricted climb advisories are the largest source of benefits. For the base case (9 sites, benefits of EDP alone), the discounted costs would be $136M, the discounted benefits would be $278M, and the benefit-to-cost ratio would be 2.05.
  - Testing limitations: None.
  - Availability of documentation : Douglas R. Isaacson ARC/AFA
- Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology: The anticipated benefits of EDP include a reduction in airborne delay for departure aircraft, reduced fuel burn and reduced noise impact due to expedited climb trajectories.

Advanced Air Transportation Technologies

Aeronautics Technology

Develop, demonstrate initial functionality, and evaluate human factors for active terminal-area decision support tool. Expedite Departure Path (EDP) will enable the more efficient management of congested terminal airspace and increased throughput at the busiest airports. This technology provides the framework for more automated terminal operations including conflict-free FMS-datalink clearances in high density terminal airspace.

The Problem:
Management and control of increasingly complex air traffic near major airports leads to excessive delay and increased resource expenditure to maintain safe separation between aircraft.

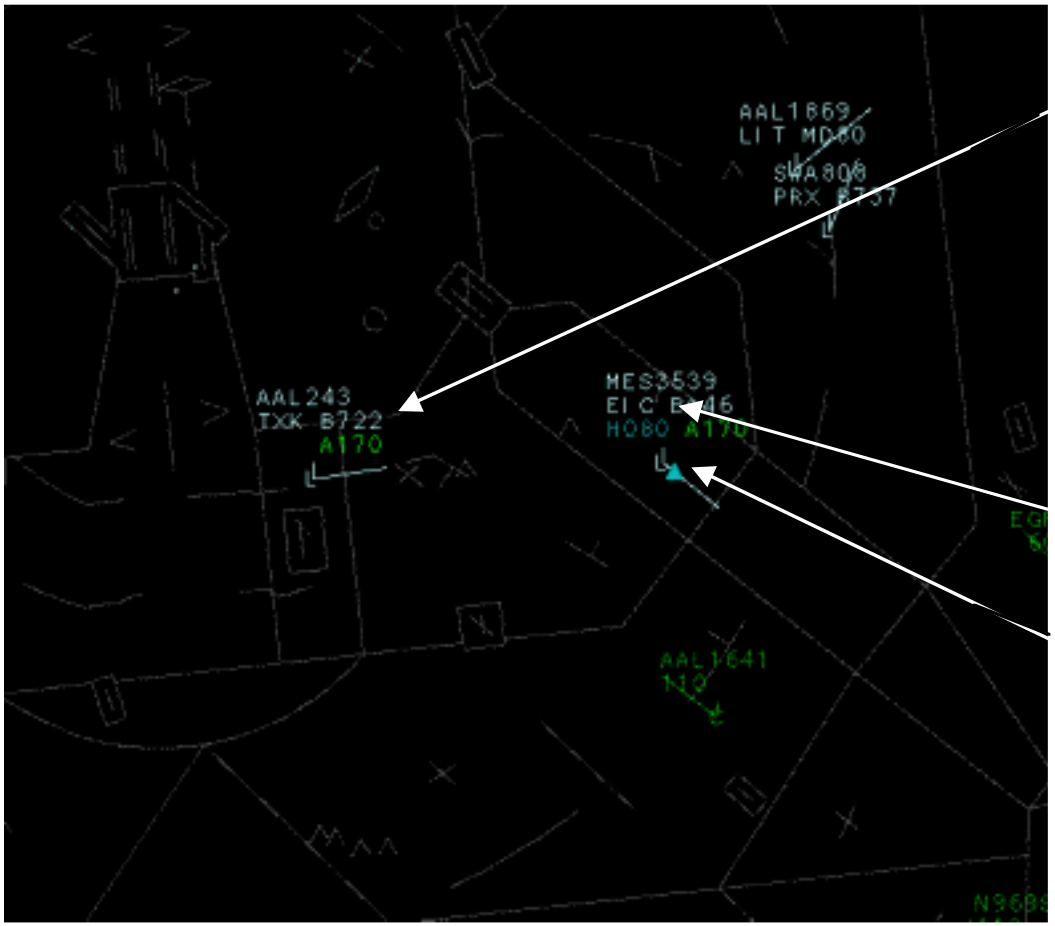
Methods:
Ongoing development of scheduling algorithms and computer human interface to assist controllers in efficiently managing high traffic throughput.

Solutions:
- Creation of an integrated conflict resolution and sequencing system for conflict-free advisory generation

- FMS-datalink of advisories allow for precision trajectory tracking in congested terminal airspace

3AATT02

EDP Controller Display



Altitude Advisory

EDP provides advisories for unrestricted climbs

Heading Advisory

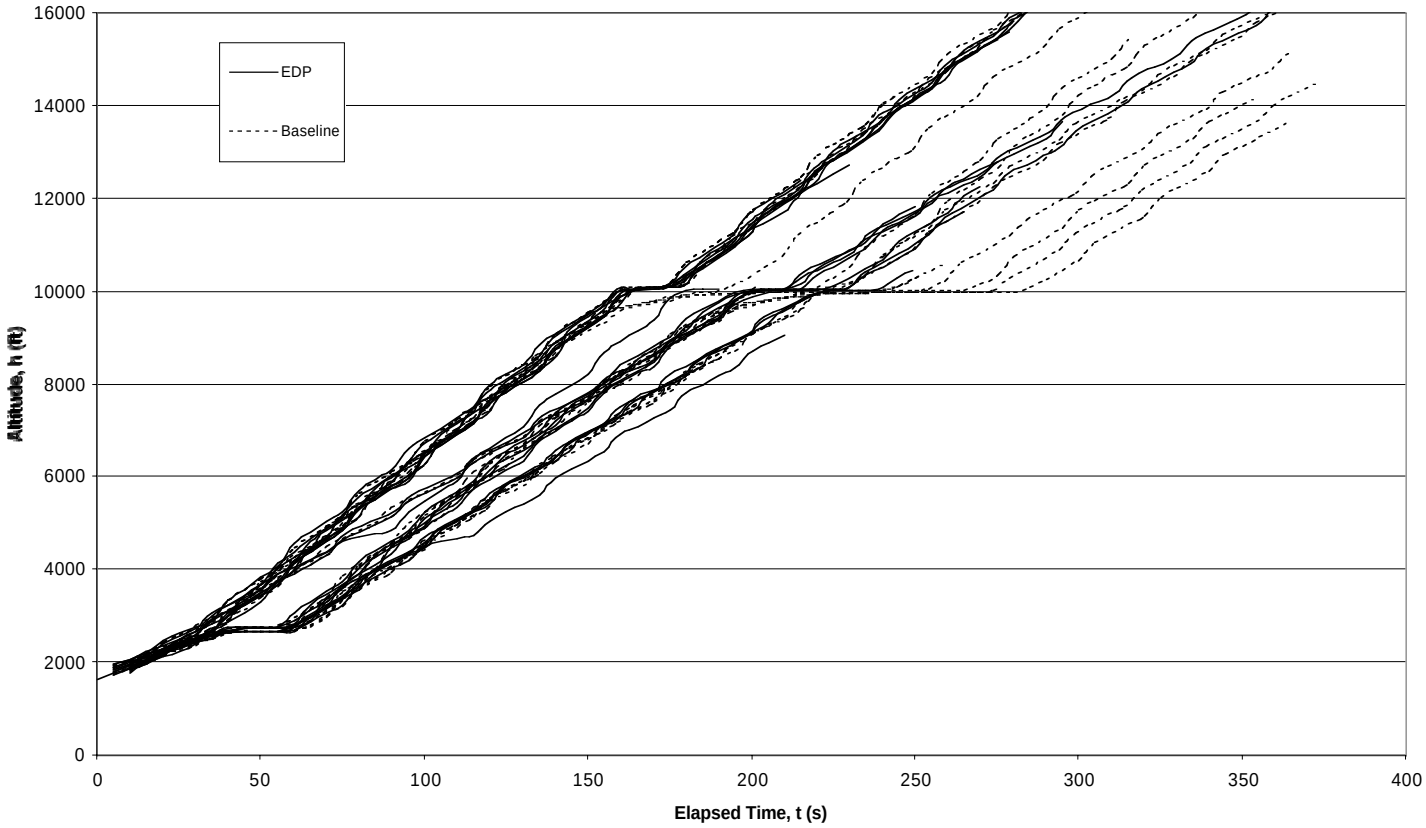
Heading Advisory Symbol

EDP provides lateral path guidance through heading advisories

EDP Metric: Improved Climb Efficiency

- From July 2003 EDP human-in-the-loop laboratory simulations
- Data for heaviest traffic scenarios showed a 200% increase in the number of aircraft directed to climb unrestricted
  - Average TRACON flying time to clear the arrival stream was reduced by roughly 10% (from 247 seconds to 219 seconds)

Sample EDP Simulation Results

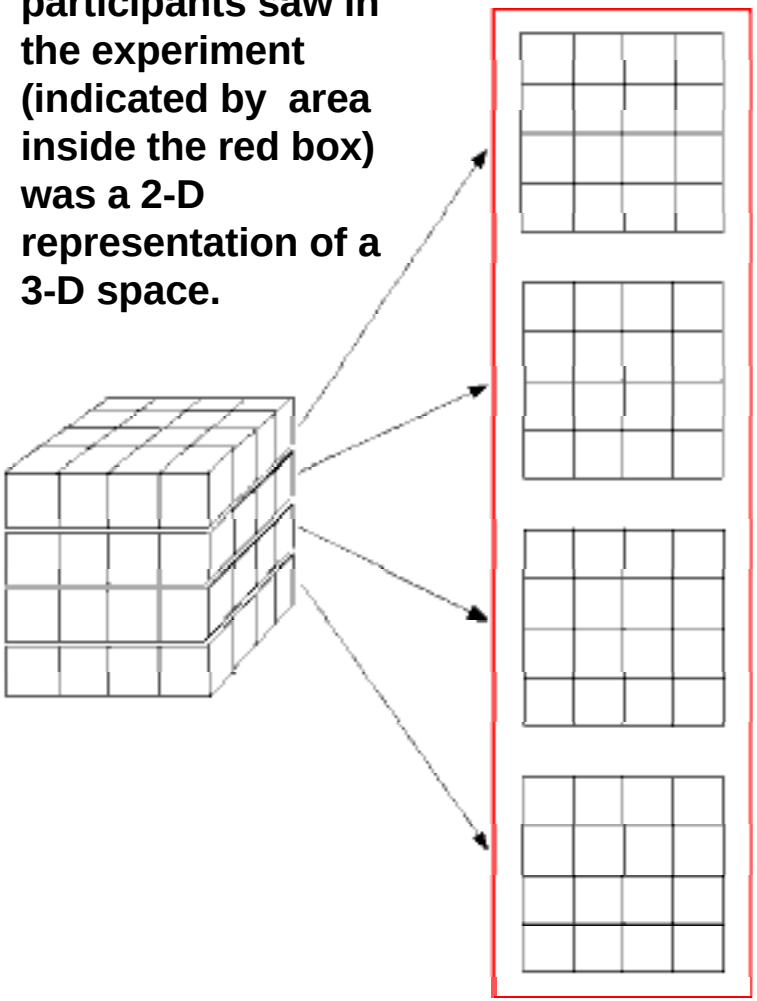


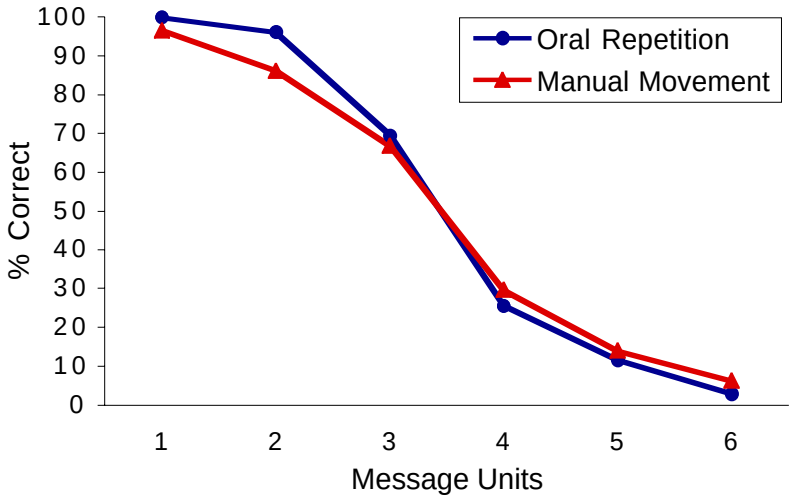
Methods to Reduce Pilot/ATC Errors

- Target: 3R1 — To complete the interim progress assessment utilizing the technology products of the Aviation Safety program, as well as the related Aerospace Base R&T efforts, and transfer to industry an icing CD-ROM, conduct at least one demonstration of an aviation safety related subsystem, and develop at least two-thirds of the planned models and simulations.
- Indicator: Provide strategies for improving training and procedures to reduce misunderstandings between pilots and air traffic controllers.
- Metric: Flight crew/Air Traffic Control performance capability improvement
- Description of activity : This investigation examined the mental representations involved in navigating in a space displayed as a grid on a computer screen, simulating pilot responses to ATC instructions. Variables included number of words, number of instructions, 2-dimensional spacing vs. 3-dimensional spacing. Subject repeated the instructions and moved manually within a grid.
- Date(s) of tests and also date for completion of data analysis: Completed May 2003
  - Results: (1) Performance was impacted more by the number of instructional units than the number of words, with a significant break between 3 and 4 instructional units; (2) Individuals performed better with a two-dimensional orientation than a 3-dimensional orientation; however, within a 3-dimensional orientation, performance was unaffected by whether the actual movement required was 3-dimensional or only 2-dimensional (emphasizing the importance of mental set in performing this task.)
  - Testing limitations: None.
  - Availability of documentation : Dr. Immanuel Barshi, ARC/IHS
- Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology: Results have been broadly presented to and received by the aviation community. Findings can be directly incorporated to improve pilot/ATC interactions, improving efficiency and safety.

Factors Influencing Repeating and Following Navigation Instructions

The display that the participants saw in the experiment (indicated by area inside the red box) was a 2-D representation of a 3-D space.





Response accuracy decreased as number of message units increased.

The experimenter explains the task to a study participant

Selected Flight Experiment Technologies

The NASA/FAA/NCAM SATS Alliance agreed to the technologies and procedures to be included in the project flight evaluations and the 2005 Technology Demonstration.

The technologies and the procedures included:

- Higher Volume Operations:
  - sequencing and self-separation algorithms
- Lower Landing Minima:
  - synthetic vision with highway-in-the-sky & velocity-vector guidance
  - enhanced vision
  - heads-up display
- Single Pilot Performance:
  - integrity monitoring
  - decision aiding
- Enroute Integration:
  - procedures for facilitating air traffic controller interaction

This accomplishment provides the suite of technologies and procedures to be developed and demonstrated, the schedule and budget estimates, and the critical path to achieving the objectives of the SATS Project.

Airspace Systems Program

Small Aircraft Transportation System - FIO

Aeronautics Technology

Target: APG3R5 - Select candidate technologies for experimental flight evaluation based on their impact on mobility. Mobility metrics will be measured by accessibility, doorstep-to-destination transit time, system and user costs, and related trip reliability and safety metrics. These flight experiments will evaluate individually, at the sub-system level, the impact of selected technologies on lowering required landing minimums and increasing the volume of operations at non-towered landing facilities in non-radar airspace during instrument meteorological conditions.

Indicator: Complete lower landing minimum flight experiment (Technology assessments for HVO and LLM flight experiments completed) GPRA 3R5b

Metric:

Description of activity (what was done and how): Lower Landing Minimum flight tests were performed by North Carolina & Upper Great Plains SATSLab in Aug-Sep, 2003. Seven experienced test subject pilots flew 3 ILS approaches using conventional CDI needles and 3 approaches using SVS/HITS display to a decision point at 200 feet and 1/2-mile visibility. Flight path accuracies were measured, and preliminary data indicated that the SVS/HITS display enables the subject pilots to fly the approach more accurately and with a reduction in workload.

- Date(s) of test and also date for completion of data analysis: August-September 2003 - Completed
- Results: Published in report from North Carolina & Upper Great Plains SATSLab.
- Testing limitations: Tests performed in VMC (simulated IMC). Other limitations for Flight Safety release described in FTO&SR document. Tests conducted with highly experienced subject pilots. Future flight tests will employ subject pilots with a broader range of experience.
- Availability of documentation (who / where): Test report - National Consortium for Aviation Mobility FTO&SR Document - Chair of LaRC Aviation Safety Review Board - Mel Lucy

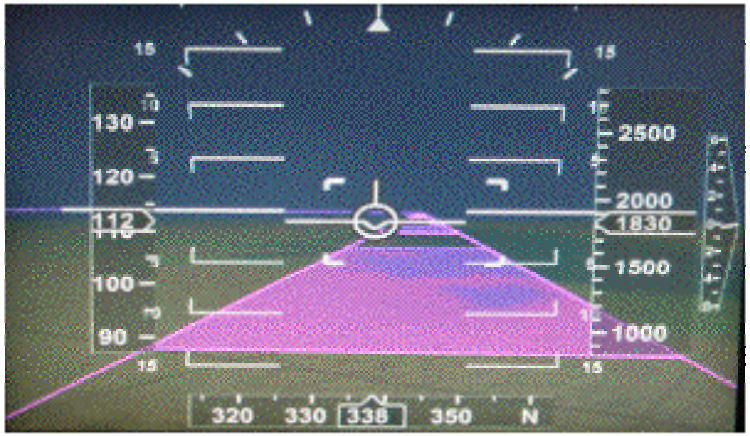
Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology: Acquisition of data is key to analysis and development of lower landing minima capability, which is one of four operating capabilities that will be demonstrated by the SATS Project.

Recovery plan (if not successful) - Successful.

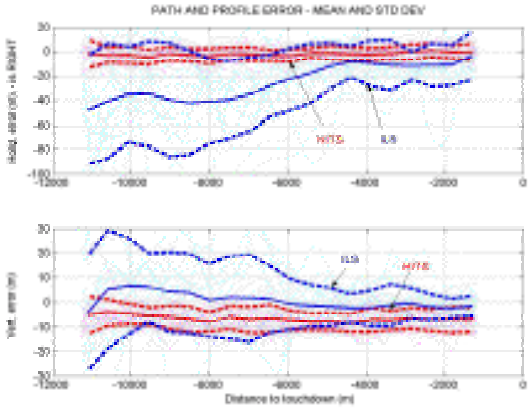
3R5b Lower Landing Minimum Flight Experiment

NC&UGP Research Aircraft

Instrument panel with MFD



HITS displayed on MFD



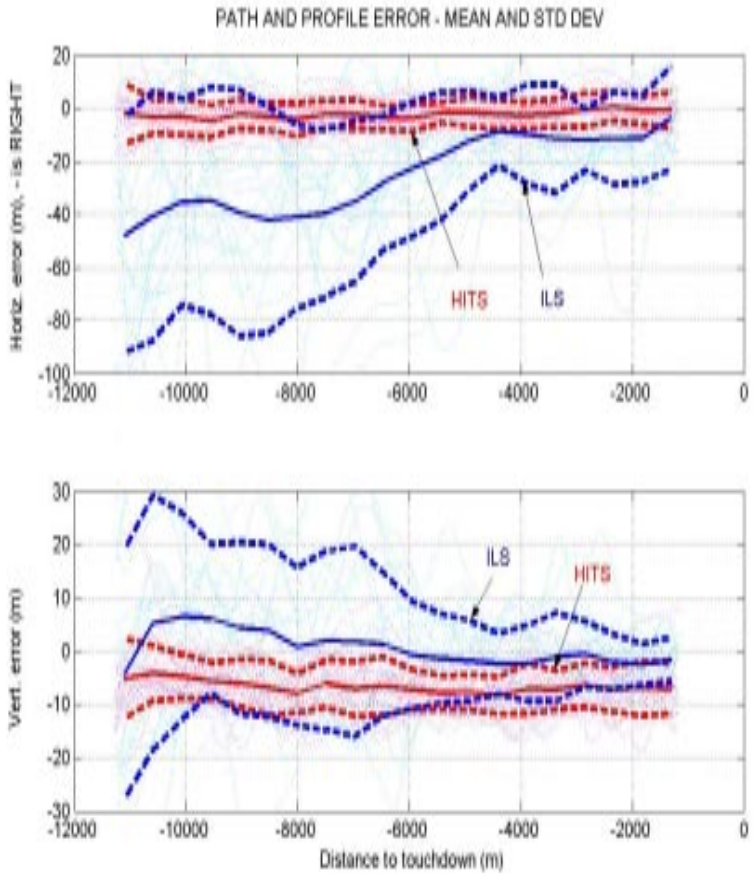
Flight path error plots

Flight Infrastructure & Operations

Complete Initial Lower Landing Minimum Flight Experiment GPRA 3R5b (9/30/03)

POC: Mitch Thomas

- NC&UGP SATSLab conducted flight tests with research equipped Aztec aircraft
- 42 Instrument Approaches (3 CDI and 3 HITS to 200 feet decision height) flown with 7 very experienced pilots.
- Average standard deviation for HITS of 6 m horizontally & 7 m vertically, compare with 30 m and 16 m for the CDI approaches



Standard deviation plots for CDI and HITS horizontal and vertical flight path error

Integrated Single Crew Flight Deck Tech.
TSAA

Target: APG3R5 - Select candidate technologies for experimental flight evaluation based on their impact on mobility. Mobility metrics will be measured by accessibility, doorstep-to-destination transit time, system and user costs, and related trip reliability and safety metrics. These flight experiments will evaluate individually, at the sub-system level, the impact of selected technologies on lowering required landing minimums and increasing the volume of operations at non-towered landing facilities in non-radar airspace during instrument meteorological conditions.

Indicator: Evaluate integrated single crew flight deck technologies (System tech assessments for integrated flight experiments completed) GPRA 3R5d

Metric:

Description of activity (what was done and how): An initial set of integrated single-crew flight deck technologies, including a Highway-in-the-Sky display, was evaluated in a flight experiment. Pilot performance was assessed during approach scenarios by comparison of actual flight path to 'Ideal' flight path, including Glide Slope (vertical path), Localizer (horizontal path), and airspeed. Pilot workload was assessed through administering the NASA-TLX Workload Survey. Workload measures included mental demand, physical demand, temporal demand, effort, performance, and frustration.

- Date(s) of test and also date for completion of data analysis: 10-21-SEP-2003 Flight Experiment
- 29-SEP-2003 Completion of Data Analysis
- Results: Pilot performance in horizontal flight path following was shown to be slightly better with the Highway-in-the-Sky than with conventional instrumentation, and pilot workload was shown to be significantly reduced, particularly for mental demand and effort measures. This experiment showed that the specific Highway-in-the-Sky guidance evaluated reduced pilot workload and enhanced performance, but did not meet the project's Single Pilot Performance minimum success criteria of enabling a median-currency private instrument-rated pilot to meet Air Transport Pilot standards of performance.
- Testing limitations: N/A
- Availability of documentation (who / where): Draft Report has been written and is available through the National Consortium for Aviation Mobility.

Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology: This experiment demonstrated the limitations as well as the benefits of currently available off-the-shelf Highway-in-the-Sky displays, and showed that improved guidance as well as additional technologies are required to meet the project's minimum success criteria of enabling a median-currency private instrument-rated pilot to meet Air Transport Pilot standards of performance.

Recovery plan (if not successful) -

Integrated Single Crew Flight Deck Technology (3R5d)
POC: Sally Johnson

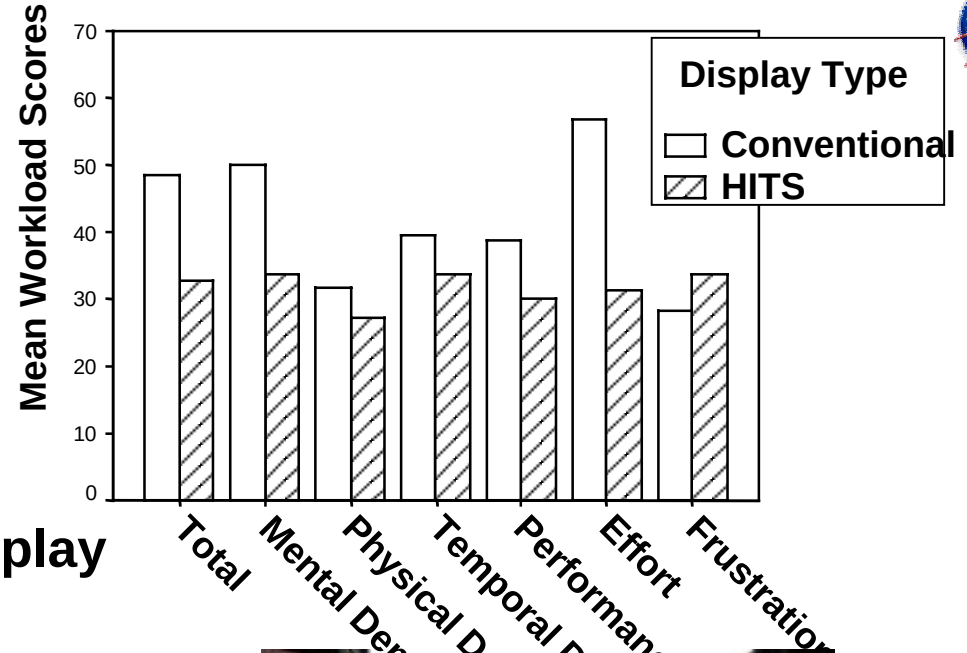
An initial set of integrated single-crew flight deck technologies were evaluated in a flight experiment.

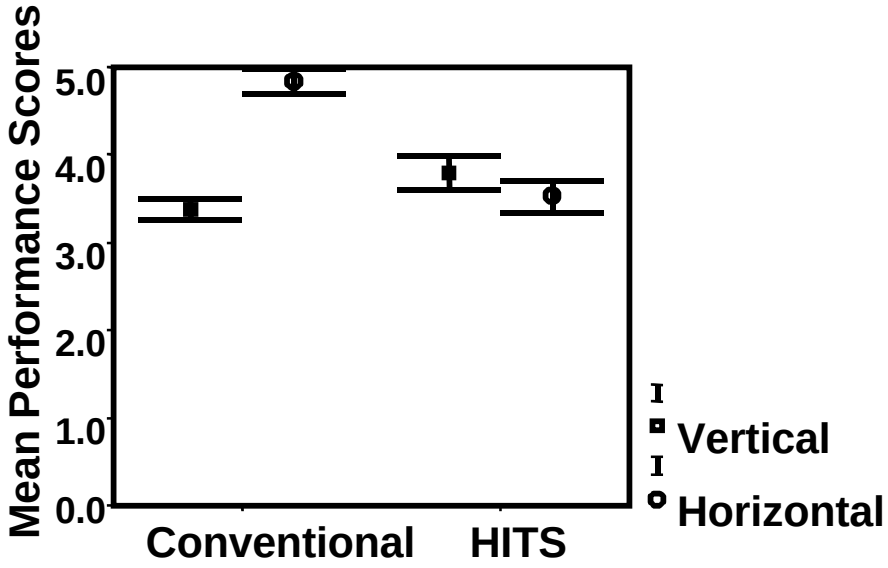
Measures: Pilot performance assessed during approach scenarios by

- Comparison of actual flight path to 'Ideal' flight path:
  - – Glide Slope (vertical path)
  - – Localizer (horizontal path)
  - – Airspeed
- Assessment of pilot workload through NASA-TLX Workload Survey:
  - Mental demand
  - Physical demand
  - Temporal demand
  - Effort
  - Performance
  - Frustration

This experiment confirmed that the specific Highway-in-the-Sky guidance evaluated reduced pilot workload and enhanced performance, but further R&D is needed to meet the project's Single Pilot Performance minimum success criteria.

Highway-in-the-Sky (HITS) Display





Conventional Instrumentation

Increased Mobility without Compromising Enroute Capacity
TSAA

Target: APG3R5 - Select candidate technologies for experimental flight evaluation based on their impact on mobility. Mobility metrics will be measured by accessibility, doorstep-to-destination transit time, system and user costs, and related trip reliability and safety metrics. These flight experiments will evaluate individually, at the sub-system level, the impact of selected technologies on lowering required landing minimums and increasing the volume of operations at non-towered landing facilities in non-radar airspace during instrument meteorological conditions.

Indicator: Demonstrate increased mobility without compromising enroute capacity (Initial mobility goal assessment completed) GPRA 3R5e

Metric:

Description of activity (what was done and how): For this activity, the Mobility analysis was used to drive the Enroute analysis. {Mobility} Using the demographic and economic data-based demand forecasts, origination/destination city-pair airports were identified and flight schedules were derived. This included identifying airports that uniquely meet the minimum criteria necessary to be considered for SATS-type as well as standard operational airports. Based upon aircraft manufacturers performance data, route structures and altitude assignments were developed reflecting the most efficient operations between the O/D city pairs. {Enroute} These were then combined with a dated selection of ETMS derived flight schedules reflecting the total traffic flown within a 24-hour period in the NAS. The combined schedules were flown in an airport-to-airport computer simulation of the NAS. Initial data analyses of the simulation results were performed examining the potential impacts of the increased level of aircraft insertions within the NAS including the enroute environment.

- Date(s) of test and also date for completion of data analysis: {Mobility} Initial travel demand forecast results generated 6/30/02. Forecasts have been updated to reflect the rapidly maturing economics of low cost business jet and air taxi business model improvements. {Enroute} Analyses remain on-going – current preliminary results completed 9/29/2003.
- Completion of full analyses anticipated by 10/31/2003.
- Results: {Mobility} The macro-economic analysis of potential trip demand for low cost air taxi system is as follows: 2010 - 16.6 Million (M) Person Round Trips (PRT) corresponding to 13.4 Billion (B) Transported-Passenger Miles (TPM's) requiring 8,298 additional business jets and 2022 - 27.0M PRT corresponding to 22.0B TPM's requiring 13,479 additional business jets. Current certification and production plans indicate that a maximum of 5000 low cost jets will be available by 2010 generating 10.0M PRT and 8.2B TPM's. {Enroute} Preliminary indications are that utilizing present ATM procedures combined with the operational procedures proposed in the various Concepts of Operations and within currently accepted air traffic growth forecasts, the SATS operations singularly may not be considered as 'compromising' the enroute capacity of the system. However it does have the potential to create capacity and operational impacts within discrete airspace areas leading to other operational constraints. Further, NAS capacities and procedural requirements may limit/constrain potential air taxi flights and mobility.

Testing limitations: {Mobility} Preliminary demand forecast was conducted using macro economic analysis rather than a detailed simulation of an Air Taxi System. Demand forecast are conservative since induced travel not considered and travel times comparisons are to commercial direct flights. {Enroute} Several concepts are still in early-development and an incomplete definition exists about some of the critical inter-relationships of the various components of the SATS operational envelope. A full NAS-level simulation study and analysis is underway with an anticipated completion date of October 31, 2003. Additional studies designed to better evaluate controller-in-the-loop and other aspects of NAS capacity impact(s) are scheduled for FY 2004.

Availability of documentation (who / where): Early results reported in (1) “Small Aircraft Transportation System Simulation Analysis of the HVO and ERO Concepts”, NASA/CR-2003-212170, Gary Millsaps and (2) “Analysis of Small Aircraft as a Transportation System”, NASA/CR-2002-211927, Sammuel M. Dollyhigh. Additional information is located within the SATS Transportation Systems Analysis & Assessment (TSAA) Element & within the Systems Analysis Branch, ASCAC, NASA Langley Research Center.

Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology:

This activity address a SATS Program Requirement derived from the Congressional Appropriation, NASA Aerospace Enterprise Mobility and Revolutionize Aviation strategies, the FAA goals for NAS safety, efficiency, cost and capacity, as well as related DoT mobility goals. The particular SATS Program requirement addressed reads: Document, by simulation, airspace modeling and analytical assessment, the impact of SATS automated flightpath management systems and operating capabilities to facilitate the integration of SATS-equipped aircraft into the NAS without compromising airspace capacity or safety.

The key technology/thrust in this TSAA activity is the development of analytical modeling and simulation tools to access the impact of:

* SATS R&T Technologies on the SATS Operating Capabilities and,
* SATS Operations on Mobility (Capacity) within the NAS

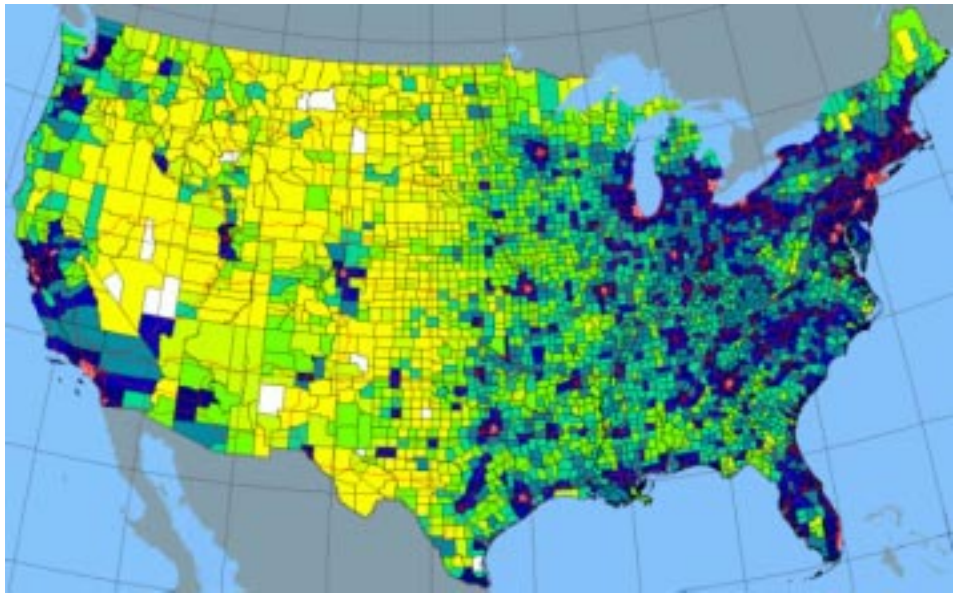
The benefit of this technology is a new modeling and simulation capability that will allow the SATS Project to “Communicate the Value of SATS to our Stakeholders & Customers”.

Recovery plan (if not successful) -

TSAA
Demonstrate increased mobility w/o compromising capacity
POC: Stuart Cooke

- Macro-economic analysis of potential trip demand for low cost air taxi system
  - 2010: 13.4B transported passenger miles, increase of 8,298 business jets
  - 2022: 22.0B transported passenger miles, increase of 13,479 business jets

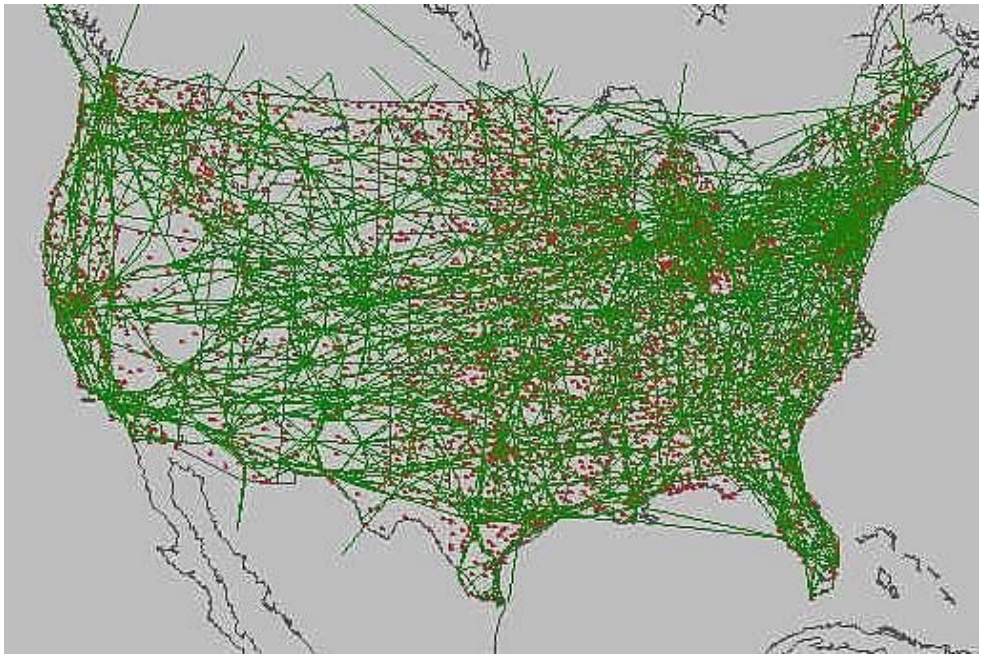
- SATS Operations
  - Economic and demographic based demand
  - Origins/destinations for typical day's operations
  - ETMS derived data for flight profiles
  - ETMS data for scheduled commercial operations



Population Densities by County

TSAA
Demonstrate increased mobility w/o compromising capacity
POC: Stuart Cooke

- Potential low cost air taxi trip demand combined with scheduled air carrier demand
- Combined schedules flown in airport-to-airport computer simulation of the NAS
- NAS capacity and procedural requirements may constrain potential air taxi flights and mobility
  - Preliminary studies indicate 2010 enroute traffic flows may not be compromised, but
  - Discrete, high-value/demand airspace traffic flows have potential to be impacted



Airspace Systems Program

Virtual Airspace Modeling and Simulation

Aeronautics Technology

- Target: 3R4c - Complete development, initial functionality and evaluate human factors for at least one decision support tool to enable achievement of the planned progress towards the goal of doubling the capacity of the National Airspace System (NAS) in 10 years. Complete the initial build of a toolbox of State-Of-the-Art (SOA) airspace models to enable the planned progress towards the 2022 Objective.

- Indicator: Complete Non-Real-Time (NRT) Build 1 SOA airspace models toolbox with ability to assess economic impact of new technology and NAS operational performance, and the ability to model the dynamic effects of interactive agents (MS-4). (NRT Build 1: Airspace Concept Evaluation System - SOA airspace models toolbox with ability to assess economic impacts of new technology and NAS operational performance and the ability to model the dynamic effects of interactive agents)

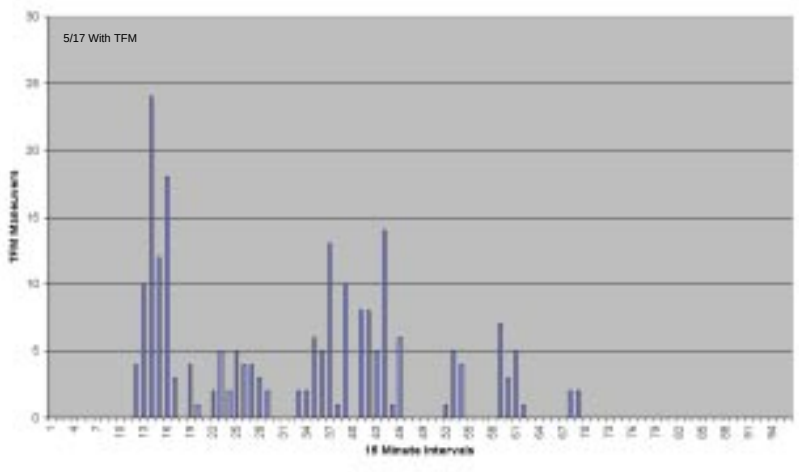
- Metric: Description of activity (what was done and how): The initial build of the Airspace Concept Evaluation System (ACES) was developed and validated. The agents and models represented interact in a manner that faithfully captures the dynamic interactions of the NAS.
  - Date(s) of test and also date for completion of data analysis: Activity began on 5/1/02 and was completed on 3/30/03. Task completed includes:
    - Architectural requirements specified that identify the high-level hardware and software requirements and their interfaces to establish the framework for the modeling system.
    - Modeling system demonstrated and validated that extends capabilities of the system prototype and simulates a current NAS concept.
    - Concept-driven requirements identified and prioritized for advanced modeling research.
  - Results: The initial build of the Airspace Concept Evaluation System (ACES) has been validated against 2 days of traffic in the NAS. The first day is a high-traffic, high-delay day and the second is a low-traffic, low-delay day. The software and validation results were documented.
  - Testing limitations: None.
  - Availability of documentation (who / where): LisaBjarke, NASA Ames Research Center, Code AFM (650) 604-0752 lbjarke@mail.arc.nasa.gov

- Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology: The NRT airspace modeling toolbox will be used in evaluating the system wide effects advanced Operational Concepts.

Complete Non-Real-Time Build 1

- Distributed simulation architecture based on DoD High Level Architecture
- Software runs in lab environment on up to 10 PCs

- Initial validation Airspace Concept Evaluation System (ACES) complete
- Results allow assessment of controller workload, delay, and fuel burned



Traffic Flow Management (TFM) actions by time of day

Vehicle Systems Program

Vehicle Systems Program

Ultra Efficient Engine Technology

Aeronautics Technology

Downselect Large Engine Contractor for Full Annular Combustor Testing TRL 5

September 2003

POC: John E. Rohde, GRC

Annual Performance Goal 3R2 Indicator: Compete and select a contractor to conduct full annular combustion testing to attain a technology readiness level of 5 based upon level of emission reduction to be demonstrated and cost to NASA.

Description of Activity: Tests were conducted in sector combustor rigs operating at simulated landing and takeoff conditions by both U.S. large engine manufacturers, General Electric Aircraft Engines and Pratt and Whitney. Each proved readiness to continue this technology development by demonstrating that the Ultra-Efficient Engine Technology (UEET) Project 70% NOx reduction goal lines can be obtained with development margin of 2% (see on accompanying chart). In addition to the NOx reduction, test requirements were met that demonstrate overall combustor mechanical and thermal component life, operability for safety of flight considerations, affordability and maintainability for product viability while exhibiting no increases in other emission constituents (carbon monoxide, smoke, and unburned hydrocarbons.) A significant reduction in cruise NOx emissions was also demonstrated.

Results: The UEET Project will not downselect, but will continue low-emission combustor development with both engine manufacturers, General Electric Aircraft Engines and Pratt and Whitney. Along with the results of the test activity described above, National Research Council guidance to not lose technology by downselecting a contractor was also considered.

Relevance: This TRL 4 tested technology will significantly reduce NOx emissions, providing a major step forward in obtaining the NASA Mission 1, Goal 2.2, ***Protect local and global environmental quality by reducing aircraft*** *noise and* ***emissions****,* by reducing NOx emissions by a factor of three in ten years.

Plans are to continue development of these low-emission combustor technologies through full-annular combustor testing to a TRL of 5 by 2005 with possible combustor testing in an engine by 2007 and possible future transition to product engine by 2010.

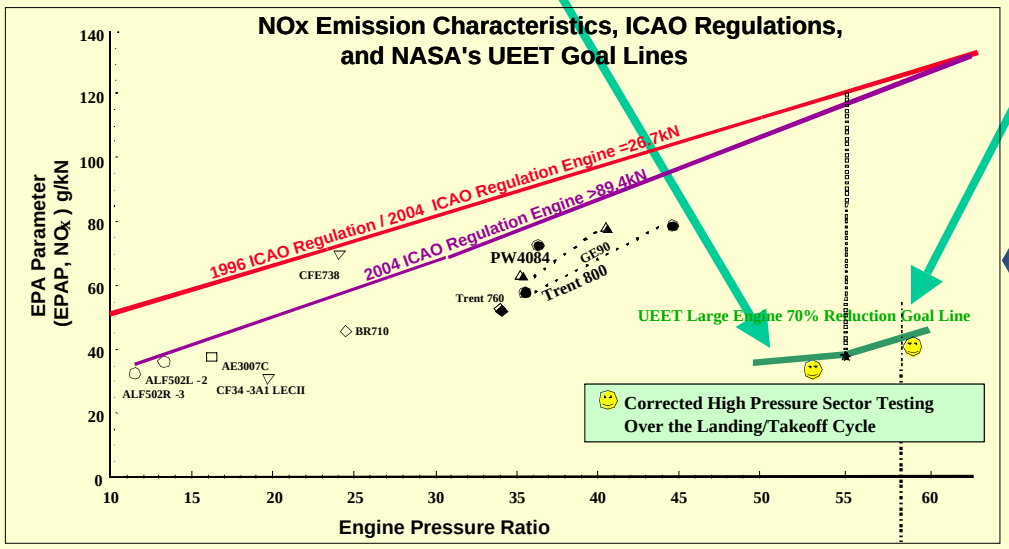
Downselect Large Engine Contractor for Full Annular Combustor Testing TRL 5

General Electric Aircraft Engines' Twin Annular Premixing Swirler (TAPS) combustion concept is a lean burning, dual-annular combustor with staging.

Proof of Concept Sector Demonstration Rig was tested at GE Evendale and high pressure tested at NASA Glenn's Advanced Subsonic Combustor Rig

Pratt & Whitney's Technology for Advanced Low NOx (TALON) combustion concept is a rich burning, single-annular combustor with no staging.

Proof of Concept Sector Demonstration Rig was tested at UTRC and high pressure tested at NASA Glenn's Advanced Subsonic Combustor Rig



- **Both exceeded stringent Ultra-Efficient Engine Technology 70% NOx reduction goal lines below the 1996 ICAO Standard over the landing/takeoff cycle**
- **Exhibited no increase in other emissions (carbon monoxide, unburned hydrocarbons, or smoke.)**
- **Exhibited significant reduction in cruise NOx emissions**
- **Demonstrated good operability and durability.**

Downselect Regional Engine Contractor for Full Annular Combustor Testing TRL=5

Annual Performance Goal 3R2: "Downselect Regional Engine Contractor for Full Annular Combustor Testing at TRL 5" Compete and select a contractor to do full annular combustion testing to attain a technology readiness level (TRL) of 5 based upon level of emission reduction to be demonstrated and cost to NASA.

Accomplishment : UEET Project downselected Rolls Royce North America to continue low-emission combustor development for regional engines through full annular combustor testing. In sector combustor rigs operating at conditions which simulate the landing and takeoff conditions, Rolls Royce North America demonstrated that the UEET 70% NOx reduction goal lines can be obtained with development margin of 2%. This engine manufacturer also demonstrated no increases in other emission constituents (CO, smoke, and unburned hydrocarbons) and a significant reduction in cruise NOx emissions. There are some concerns with the manufacturing method of the low emission fuel injector and maintainability for product viability that still need to be verified with a fuel injector manufacturer and Rolls Royce North America.

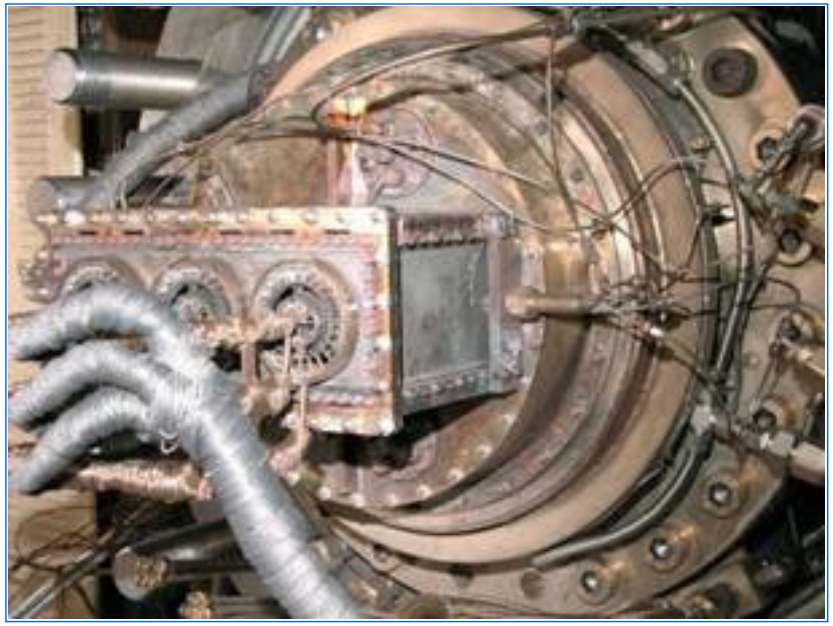
Relevance: This TRL 4 tested technology will significantly reduce NOx emissions providing a major step forward in obtaining the NASA Mission 1, Goal 2.2, ***Protect local and global environmental quality by reducing aircraft*** *noise and* ***emissions****,* by reducing NOx emissions by a factor of three in ten years.

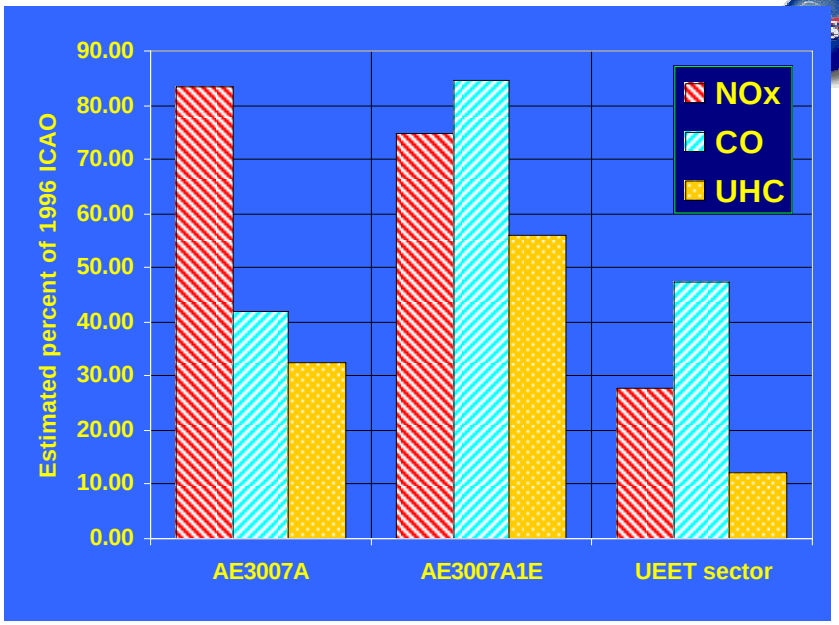
Plans are to continue development of these low-emission combustor technologies through full-annular combustor testing to a TRL of 5 by 2005 with possible combustor testing in an engine by 2007 and possible future transition to product regional engine by 2010.

POC: John E. Rohde, GRC

Downselect Regional Engine Contractor for Full Annular Combustor Testing TRL=5

Aeronautics Technology





Proof of Concept Sector Demonstration Rig which was tested both at Rolls Royce North America (RRNA) (low pressure) and in NASA Glenn's Advanced Subsonic Combustor Rig (high pressure) in June-July 2003.

RRNA's Low-Emission Combustion Concept is a **lean burning, single-annular combustor with concentric-staged fuel injection** and separate pilot and main combustion for high combustion efficiency at idle and low power operation.

As Shown, the U.S.Engine Manufacturer Rolls Royce North America (RRNA):

- Exceeded stringent UEET 70% NOx Reduction goal based on the 1996 ICAO Standard over the landing/takeoff cycle;
- Exhibited no increase in other emissions (CO, UHC or Smoke) from standard,
- Exhibited significant reduction in cruise NOx emissions, and
- Demonstrated good operability and durability.

Also shown are the RRNA commercial regional jet engines in-service the AE3007A and AE3007A1E.

Complete Sector Evaluations of 70% LTO NOx Configurations

Annual Performance Goal 3R2: "Complete sector evaluations of 70% LTO NOx configurations"
In combustor sector tests, demonstrate a >70% reduction in the production of nitrogen oxides (NOx) relative to 1996 International Civil Aviation Organization (ICAO) standard over the landing/takeoff cycle.

Accomplishment: The major U.S. engine manufacturers, General Electric Aircraft Engines, Pratt and Whitney, and Rolls Royce North America, demonstrated the viability of a major Ultra-Efficient Engine Technology Program goal. Tests proved that the 70% NOx reduction goal lines (indicated by ☹ on accompanying chart) can be obtained with a development margin of 2% in sector combustor rigs operating at simulated landing and takeoff conditions. These low emission sector combustors demonstrated the NOx goal without increases in other emission constituents (carbon monoxide, smoke, and unburned hydrocarbons). Testing was conducted from May to September 2003.

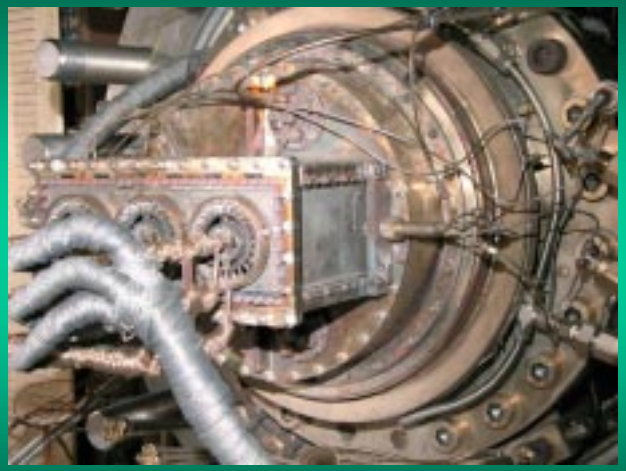
Relevance: This technology readiness level (TRL) 4 tested technology will significantly reduce NOx emissions providing a major step forward in obtaining the NASA Mission 1, Goal 2.2, ***Protect local and global environmental quality by reducing aircraft*** *noise and* ***emissions****,* by reducing NOx emissions by a factor of three in ten years.

Plans are to continue development of these low emission combustor technologies through full annular combustor testing to a TRL of 5 by 2005 with possible combustor testing in an engine by 2007 and possible future transition to a product engine by 2010.

POC: John E. Rohde, GRC

Complete Sector Evaluations of 70% LTO NOx Configurations

Rolls Royce North America



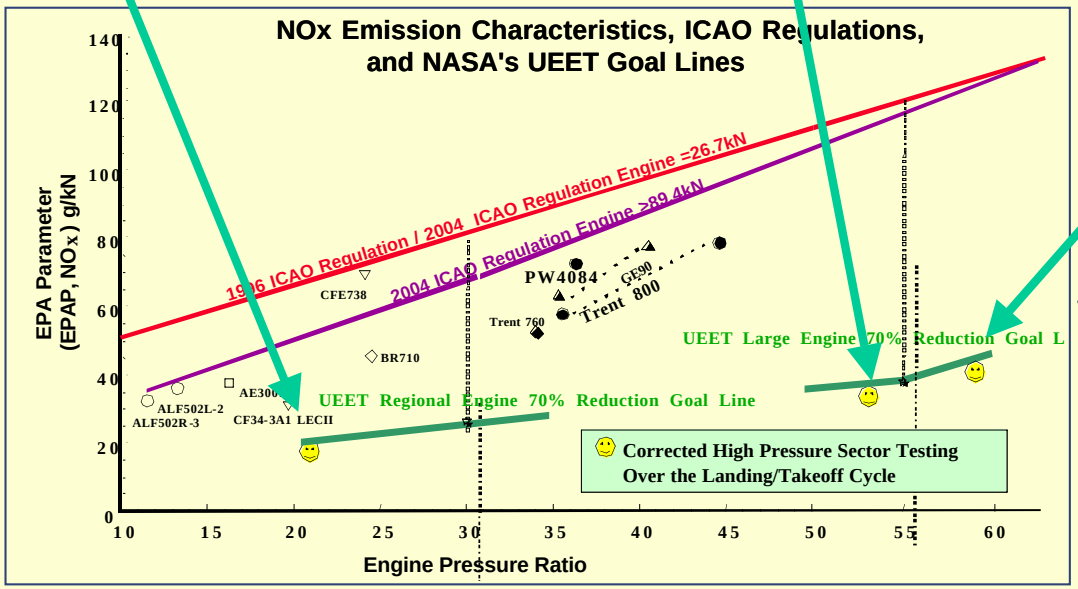
Twin Annular Premixing Swirler (TAPS)
Proof of Concept Sector Demonstration Rig

General Electric Aircraft Engines

Twin Annular Premixing Swirler (TAPS)
Proof of Concept Sector Demonstration Rig

Pratt and Whitney

Technology for Advanced Low NOx (TALON) X
Proof of Concept Sector Demonstration Rig

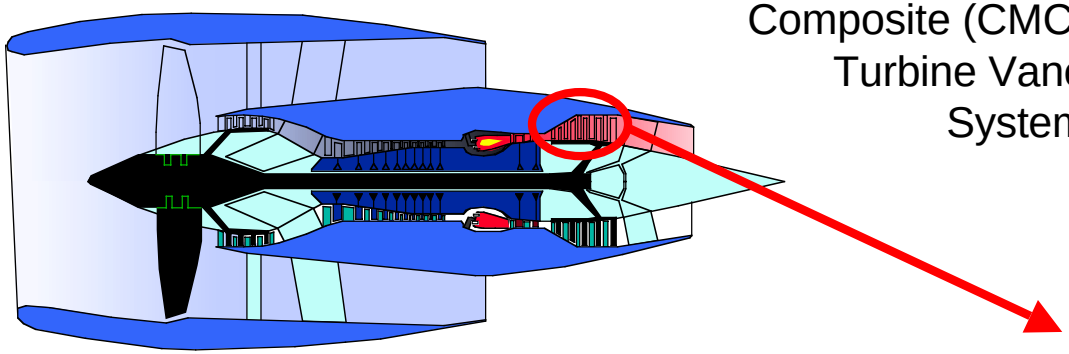


- Exceeded stringent Ultra-Efficient Engine Technology 70% NOx reduction goal lines below the 1996 ICAO Standard over the landing/takeoff cycle.
- Exhibited no increase in other emissions (carbon monoxide, unburned hydrocarbons, or smoke).
- Demonstrated good operability and durability.

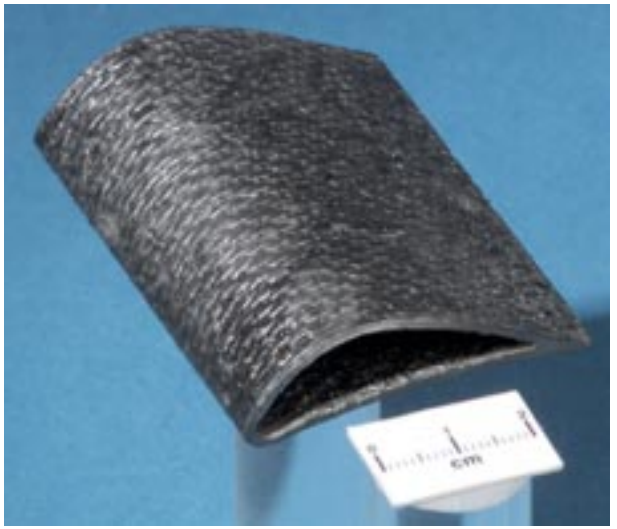
Material System for CMC Turbine Vane

- Target: 3R2-- "Complete an Interim Technology Assessment of the aggregate potential benefits from the engine technologies to reduce emissions." This CMC vane technology will feed the assessment, which will provide a benchmark for measuring overall progress towards the emissions goals.
- Indicator: Develop a ceramic matrix composite (CMC) turbine vane.
- Metric: Demonstrate 2400°F CMC for vane application and 2700°F Environmental Barrier Coating (EBC) system
- Description of activity: CMC materials were produced and evaluated by thermal and mechanical tests intended to encompass the design space required for CMC vane application. Chemical stability tests were used to evaluate EBCs in high temperature water vapor, simulating a combustion environment.
  - Date(s) of tests and also date for completion of data analysis: All necessary tests are complete.
  - Results: 2400°F capability demonstrated (meets goal) for CMC. Laboratory coupons survived 500 hot hours at 2400°F at stresses calculated for vane application (meets goal). Laboratory coupons coated with the Environmental Barrier Coating (EBC) demonstrated durability and chemical stability at 2700°F.
  - Testing limitations: None.
  - Availability of documentation: James DiCarlo, GRC/5120, Kang Lee, GRC/5130, Anthony Calomino, GRC/5920
- Importance to customer/How and how much it supports Enterprise/benefits of technology:
  - This new material system will significantly increase temperature capability of the high pressure turbine. This has the effect of increasing engine turbine efficiency and reducing emissions.
  - The CMC system has 1/3 the density of material it replaces, thus reducing component, subsystem and engine weight.

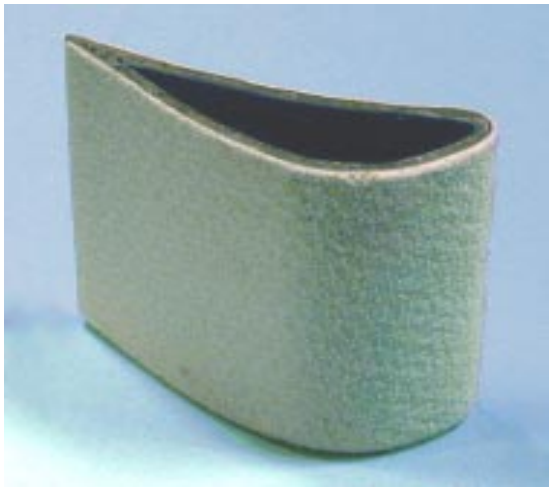
Material System for CMC Turbine Vane



Ceramic Matrix Composite (CMC) Turbine Vane System



Establishment of a 2700ºF CMC vane system will increase turbine efficiency and reduce carbon dioxide (CO_2) emissions of advanced aircraft engines

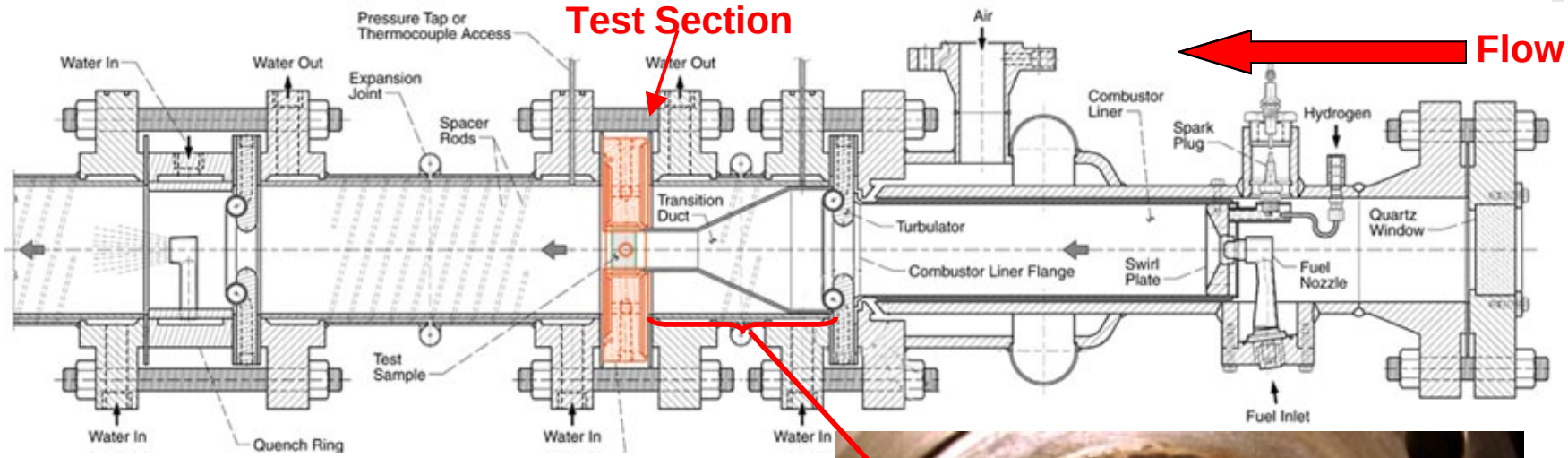


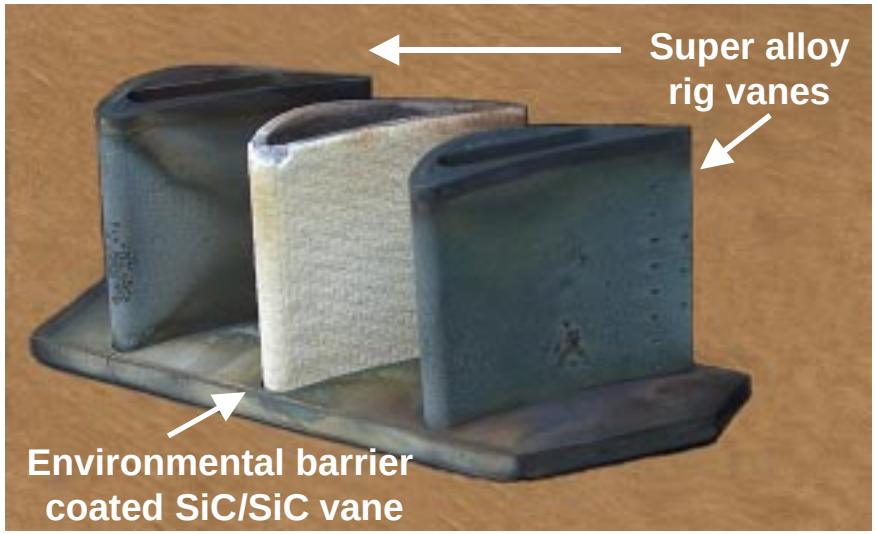
CMC with Environmental Barrier Coating (EBC)

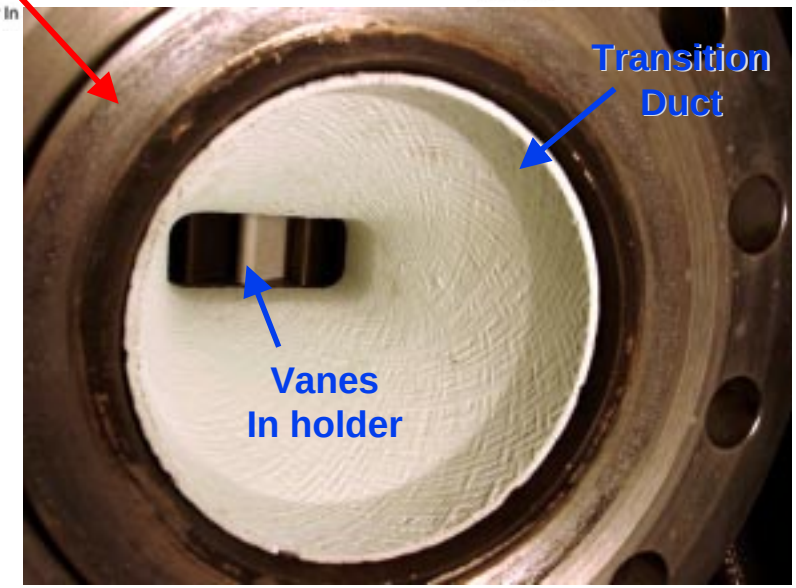
Demonstrate a CMC Complex Part in Rig Test

- **Annual Performance Goal (3R2) Indicator:** "Demonstrate a CMC Complex Part in Rig Test" A 2700ºF ceramic matrix composite (CMC) system for turbine section application will demonstrate a first-stage vane application. Durability of the vane, material system, and coating system will demonstrate viability of the advanced, non-metallic composite in a rig test. Demonstrate CMC system capability by testing a CMC vane or vane subcomponent in a burner rig with a thermal gradient of at least 250ºF across the 2700ºF environmental barrier coating for 50 cycles. Demonstrate surface temperature capability of 2550-2650ºF.
- **Accomplishment**: Performed cyclic thermal gradient burner rig test of Ceramic Matrix Composite vane in the NASA GRC High Pressure Burner Rig. Testing was conducted for 100 cycles at varying flow and temperature and 50 hours at constant flow and temperature. CMC component performance met minimum success criteria. Test temperatures were limited by ancillary metal hardware. Testing was conducted September 2003.
- **Relevance**: This test demonstrated the viability of a CMC material with structural capability to 2400ºF and an environmental barrier coating with 2700ºF surface temperature capability for turbine vane applications. Fiber architecture and attachment techniques were developed for turbine vane shapes. The long-term durability of a CMC vane system will be demonstrated in subsequent rig tests. This accomplishment directly supports the Aerospace Technology Enterprise, Aeronautics Technology Theme, NASA Mission 1, Goal 2, Objective 2.2 to ***Protect local and global environmental quality by reducing aircraft*** *noise and* ***emissions.***
- **POC**: Michael Verrilli, GRC, Craig Robinson, QSS @ GRC

Cyclic thermal gradient burner rig test of CMC vane





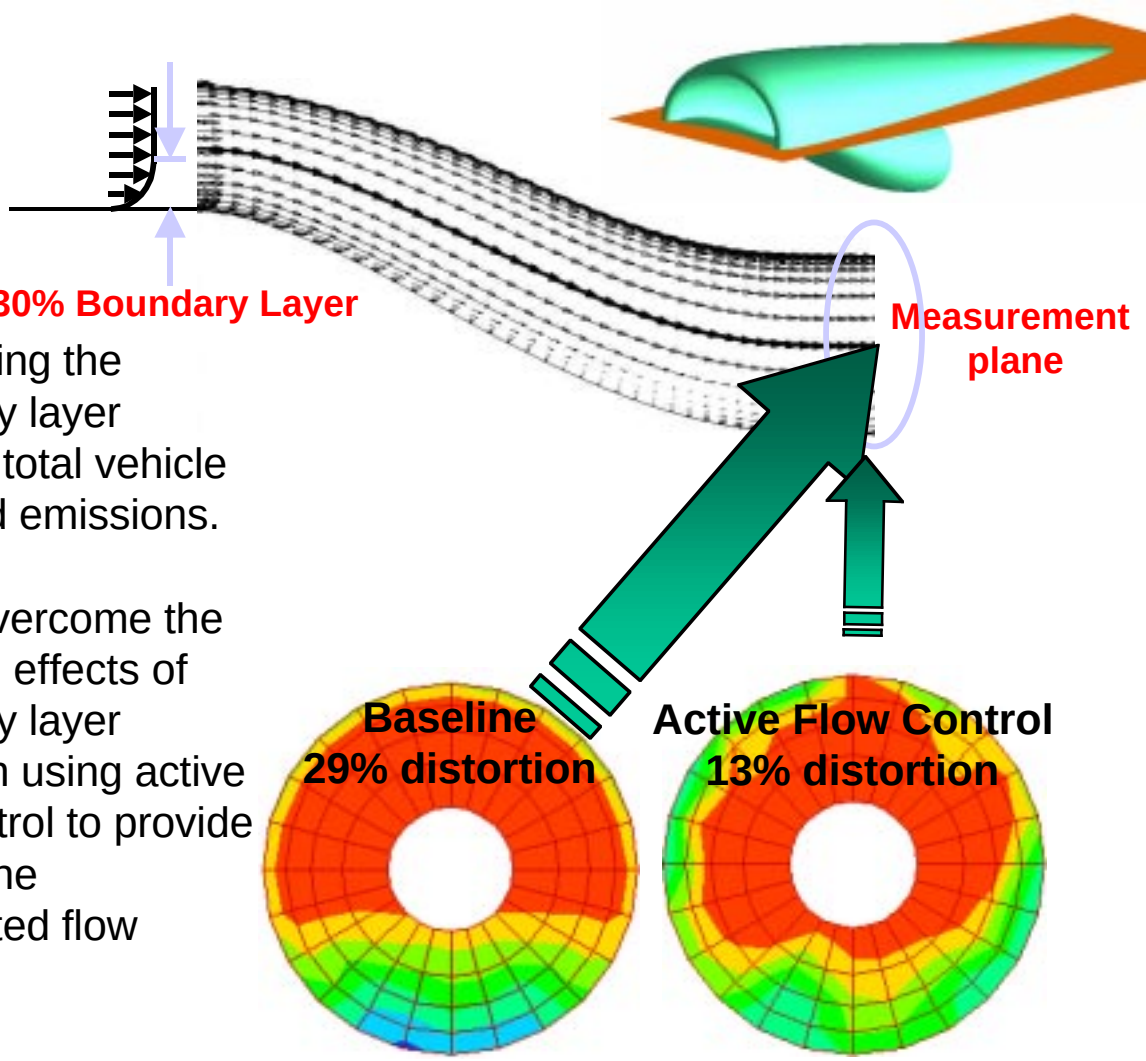


Active Flow Control Concepts for Propulsion Airframe Integration

- Target: M1514-A02-- "Evaluate Active Flow Control Concepts for Propulsion Airframe Integration." This inlet technology will reduce total vehicle drag, resulting in less fuel burn and reduced emissions.
- Indicator: Develop active flow control for a boundary-layer-ingesting, small-scale, offset diffuser.
- Metric: Demonstrate inlet distortion less than 20% with pressure recovery of 0.985. Identify scaling parameters for flow control at large scale.
- Description of activity: Active flow control was demonstrated on a small-scale inlet with 30% boundary layer ingestion in the Basic Aerodynamics Research Tunnel. Inlet distortion and pressure recovery were measured, and distortion sensitivity to actuator parameters was documented.
  - Date(s) of tests and also date for completion of data analysis: Testing complete 11/02. Data analysis complete 3/03.
  - Results: Distortion reduced from 29% to 13% (exceeds goal) with pressure recovery above 0.985. Mass flow required for active flow control actuators was less than 1% of inlet mass flow. Scaling parameters were identified as actuator mass flow and jet to freestream velocity ratio.
  - Testing limitations: Tests were limited to Mach numbers of 0.1 and 0.15
  - Availability of documentation: Susan Gorton, LaRC/5059, Lewis Owens, LaRC/5127

– Importance to customer/How and how much it supports Enterprise/benefits of technology:
  - The inlet distortion with active flow control is within operational limits for military aircraft and close to the 10% level required for commercial operations. This has the effect of making boundary layer ingestion a feasible way to reduce drag and emissions.
  - This technology directly supports Aeronautics Technology Mission 1, Goal 2.2.

Active Flow Control Reduces Inlet Distortion for a BLI Inlet



Swallowing the boundary layer reduces total vehicle drag and emissions.

Goal: overcome the negative effects of boundary layer ingestion using active flow control to provide the engine undistorted flow

6% model in BART

8 Actuators and manifold

Interim Technology Benefits Assessment

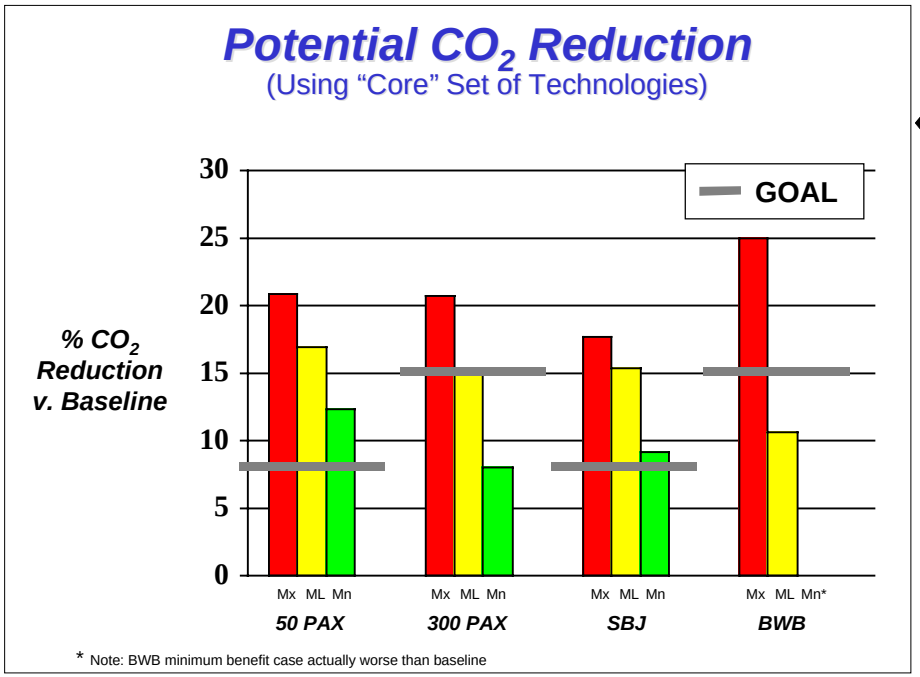
- **Annual Performance Goal Indicator**: "Interim Technology Benefits Assessment." This effort will assess all technologies of the Ultra-Efficient Engine Technology (UEET) Program for their impact on meeting program goals for four classes of aircraft. Include assessment of performance, weight, environmental, atmospheric & economic assessments. Identify shortfalls in meeting program goals and make recommendations to reduce program risks.

- **Accomplishment:** Conducted technology benefits assessment for a 50-passenger subsonic airplane, 300-passenger subsonic airplane, supersonic business jet, and blended wing body vehicle. Examined three levels of impacts of the technologies: maximum, most likely, and minimum benefit. Despite continuing shifts in tech portfolio, results indicate that UEET technologies have potential of meeting, or exceeding, program's emission reduction goals. Technology Audit completed 6/30/03. Technology benefits assessment completed 8/30/03. Milestone documentation completed 9/30/03.

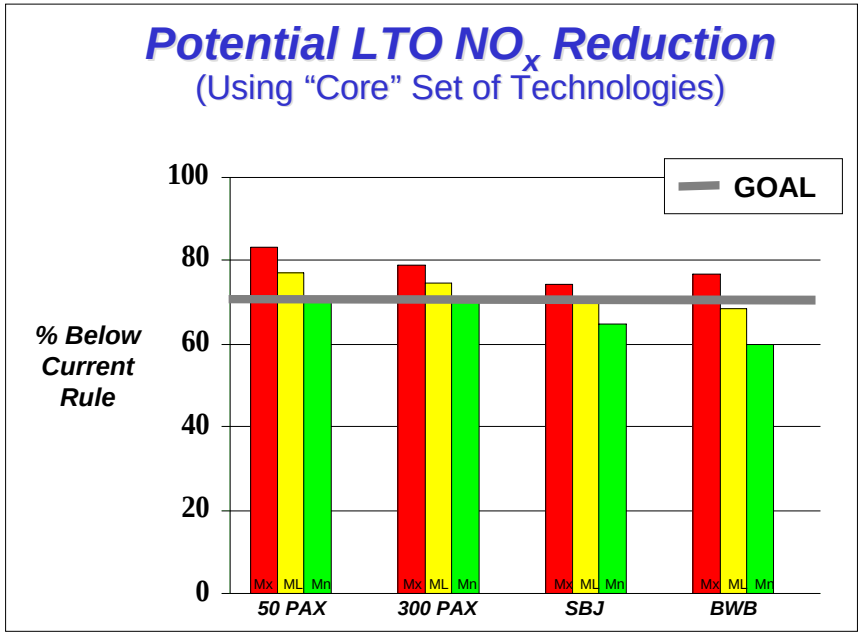
- **Relevance:** Results of these assessments are important because they (1) reflect progress toward system goals, (2) provide insights into which technologies are providing the biggest payoffs toward the system goals, (3) and help guide technology portfolio investment decisions. This accomplishment directly supports the Aerospace Technology Enterprise, Aeronautics Technology Theme, NASA Mission I, Goal 2, Objective 2.2 to *Protect local and global environmental quality by reducing aircraft noise (secondary) and emissions (prime).*

- **POC:** William Haller, GRC/2400, Mary Jo Long-Davis, GRC/2600

Interim Technology Benefits Assessment



Potential Maximum CO2 Reduction and Landing & TakeOff (LTO) NOx Reduction for all 4 vehicles exceeds program goals



"Core" Set= primary group of technologies that can be modeled together

Three-Dimensional Noise Propagation Code for Engine Nacelles (GPRA 3R3a)

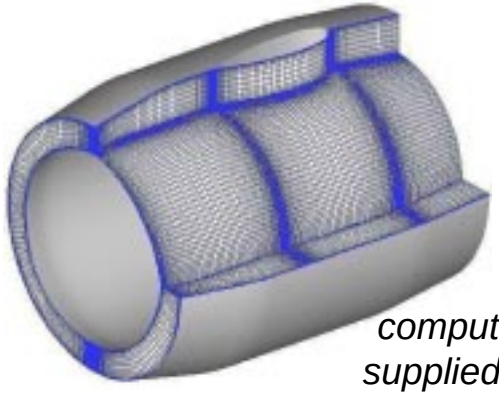
Target: APG3R3 - Complete development of initial physics-based prediction models to guide the development potential noise reduction technology concepts. Complete an interim technology assessment of the potential benefits for these concepts to reduce noise emissions. The results from this analysis will provide a benchmark for measuring overall progress, and guide future investment decisions.

Description of activity (what was done and how): The development of this three-dimensional noise propagation code for engine nacelles uses a modular approach with a main goal of providing a physics-based tool within a user friendly environment to enhance prediction of fan noise. The Grid Generation Module provides the capability to automatically generate numerical grids, thereby simplifying this time-consuming process. The Background Flow Module uses a well tested and robust flow solver to produce engine flow solutions. The flow quantities and the acoustic grid are used within the Acoustic Propagation Module to calculate acoustic quantities within the nacelle. Acoustic propagation results are then used within the Acoustic Radiation Module to obtain the radiated noise.

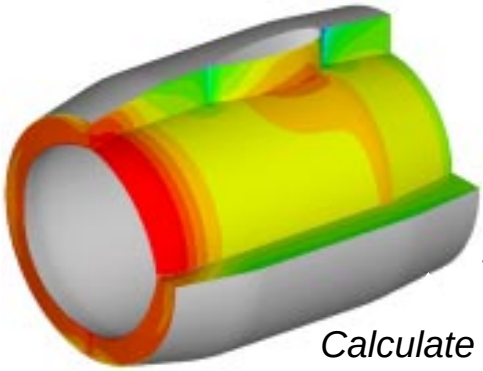
- Date(s) of test and also date for completion of data analysis: N/A
- Results: The ability to handle complex geometries allows investigation into the effects of many design parameters (e.g., acoustic liners, splitters, pylons, curved ducts, etc.)
- Testing limitations: N/A
- Availability of documentation (who / where): Bill Willshire, LaRC, Linda Bangert, LaRC

Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology: Developing physics-based noise prediction models is the key to discovering and optimizing technologies to make aircraft quieter. These tools also enable industry to optimize NASA-developed technologies for their own product lines, thus reducing the risk that the technology will be implemented. Directly supports NASA Mission 1, Goal 2.2: Protect local and global environmental quality by reducing aircraft noise and emissions.

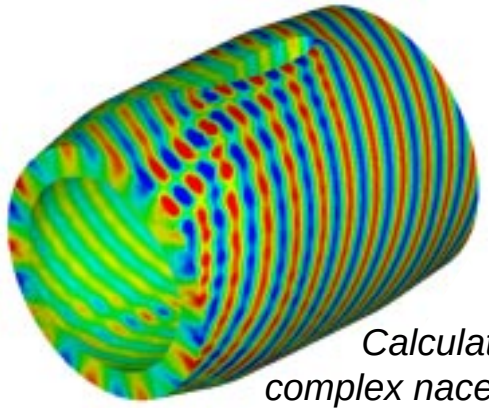
Three-Dimensional Noise Propagation Code for Engine Nacelles



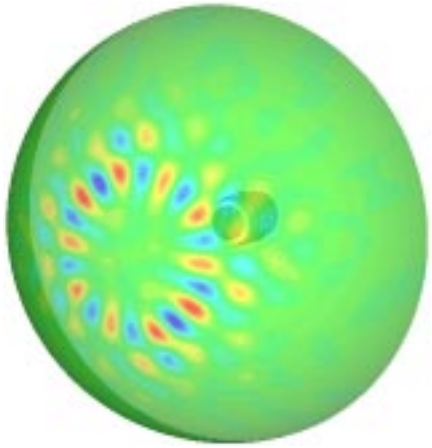
Step 1: Grid Generation Module
Automatically create computational grids from user-supplied geometry for both flow and acoustic (noise) calculations



Step 2: Background Flow Module
Calculate engine flow quantities



Step 3: Acoustic Propagation Module
Calculate acoustic quantities within complex nacelle geometry (e.g., acoustic liners, splitters, pylons, curved ducts, etc.)



Step 4: Acoustic Radiation Module
Calculate radiated noise

Develop Initial Physics-Based Noise Prediction Models (GPRA 3R3b, 3R3e)

Target: APG3R3 - Complete development of initial physics-based prediction models to guide the development potential noise reduction technology concepts. Complete an interim technology assessment of the potential benefits for these concepts to reduce noise emissions. The results from this analysis will provide a benchmark for measuring overall progress, and guide future investment decisions.

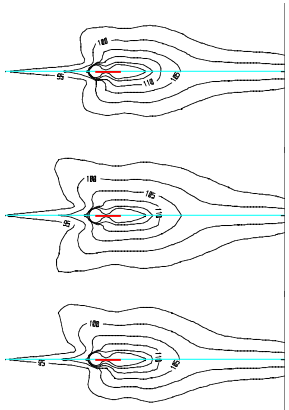
Description of activity (what was done and how): The physics-based models which have been developed are related to noise generation and propagation physics for airframe and engine noise sources as well as noise interaction between the engine and airframe. These models describe the physical processes involved inflowfield fluctuations and structural interaction that produce or modify noise for various components. Such descriptions must be established via flowfield and noise measurement experiments and computation.

- Date(s) of test and also date for completion of data analysis: N/A
- Results: Specific models which were developed to deal with the propagation of noise include the effect of weather on community noise levels, scattering of engine noise by the airframe (wings and fuselage), and propagation of engine noise (including noise absorbed by liners) through the engine nacelle to the area around the airplane. Models were also developed to predict the noise created by flowfield fluctuations around landing gear, between the leading edge slat and main wing, and between fan blades and stator vanes inside an engine. Understanding the details of noise production and propagation is essential for the discovery and development of advanced noise reduction concepts.
- Testing limitations: N/A
- Availability of documentation (who / where): BillWillshire, LaRC, Linda Bangert, LaRC

Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology:
Developing physics-based noise prediction models is the key to discovering and optimizing aircraft noise reduction technologies. These tools also enable industry to optimize NASA-developed technologies for their own product lines, thus facilitating technology implementation in the fleet. Directly supports NASA Mission 1, Goal 2.2: Protect local and global environmental quality by reducing aircraft noise and emissions.

Complete development of initial physics-based prediction models to guide the development of potential noise reduction technology concepts

Effect of weather on predicted community noise levels

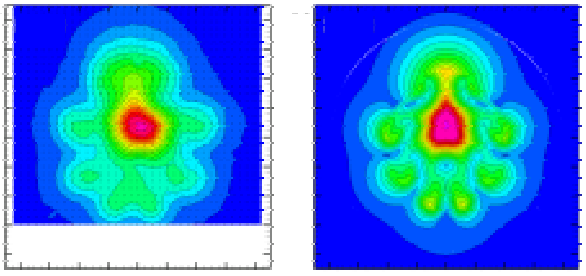


Cloudy, calm day

Clear, calm night (temperature inversion)

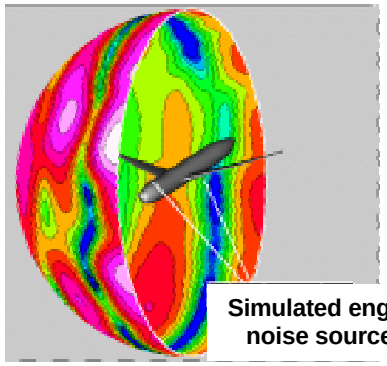
Cloudy, 5 knot wind

Jet exhaust flowfield modeling enables noise prediction for unconventional configurations



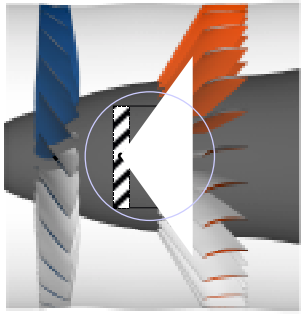
Experiment Computation

Prediction of noise scattered by airframe

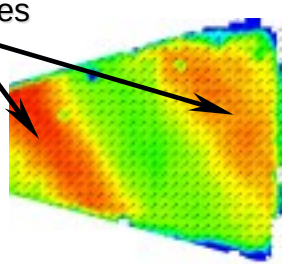


Simulated engine noise sources

Experimental diagnosis of engine fan wakes to reduce fan noise

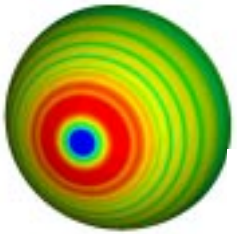


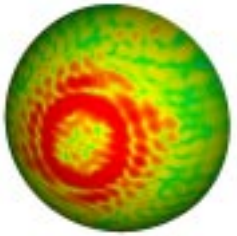
Fan Wakes



Code development to predict noise propagation from an engine nacelle

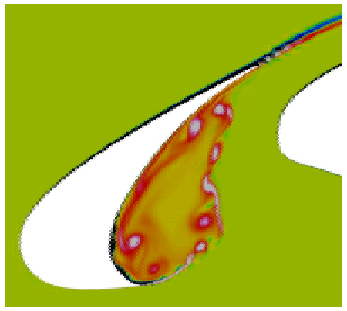
Radiated sound from straight annular duct



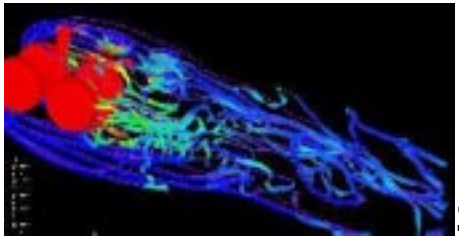


Radiated sound from a small business jet duct with realistic pylons

Modeling of flow between leading edge slat and wing for noise prediction

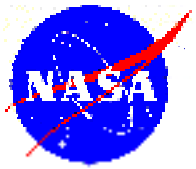


Modeling of flow and noise prediction for landing gear



3QAT02

Complete an interim technology assessment of the potential benefit of these concepts to reduce noise emissions



Annual Performance Goal: "Complete an interim technology assessment of the potential benefit of these concepts to reduce noise emissions." The results from this analysis will provide a benchmark for measuring overall progress, and guide future investment decisions.

Accomplishment: A technology assessment was conducted within the Quiet Aircraft Technology (QAT) Project to measure the projected benefit of developed technologies against the baseline aircraft (a long-range twin). The methodology employed is the same as that used for the evaluation of the AST program noise reduction goals. The projected benefit of both airframe and engine noise reduction technology concepts was collected from all of the areas of study under the QAT project. These benefits have been evaluated using the existing baseline engine cycle and proposed advanced engine cycles on aircraft planforms with airframe noise reduction technology benefits included.

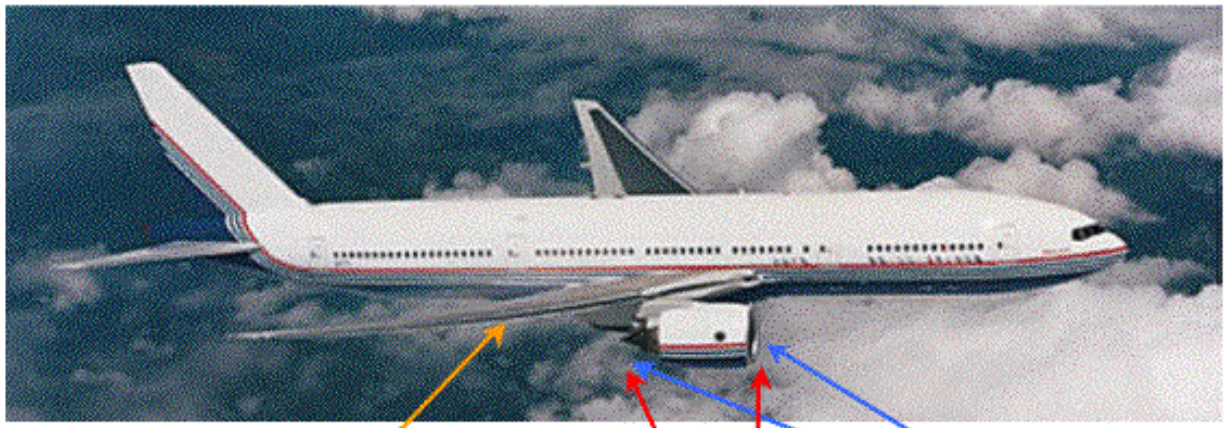
It was determined that, with the use of advanced engine cycles (such as the geared turbofan) together with the other engine and airframe noise reduction concepts installed on the baseline aircraft, the QAT goal of reducing aircraft system noise by 10 dB can be achieved.

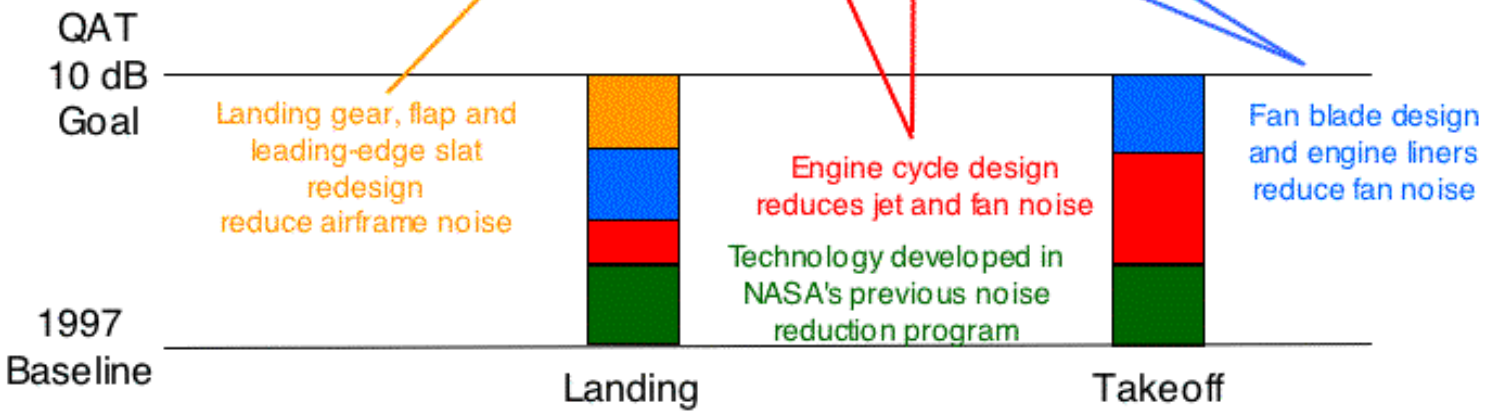
Relevance: Assessing the benefit of technologies developed thus far in the Quiet Aircraft Technology Project will allow future decisions on what technologies are most promising and should be further matured. Directly supports NASA Mission 1, Goal 2.2: *Protect local and global environmental quality by reducing aircraft noise and emissions*.

POC: Bill Willshire, LaRC, Linda Bangert, LaRC

Achieving Quiet Aircraft Technology Goals

Baseline - 777-Class Aircraft / Bypass Ratio 8 Engines





Technology Benefits On Future Vehicle Concepts

- **Annual Performance Goal:** Complete combustor sector test for concepts capable of achieving the 70% NOx goal by 2007 and select the most promising approaches leading to full annular rig testing for large and regional jet engine applications. Complete an Interim Technology Assessment of the aggregate potential benefits from the engine and airframe technologies to reduce emissions. The results from this analysis will provide a benchmark for measuring overall progress, and guide future investment decisions.
- **Accomplishment:** Using state of the art conceptual analysis tools, a quantitative assessment of the TCAT technology portfolio's impact on CO_2 reduction for future vehicle concepts has been completed. This assessment included the impact of these technologies on the projected year 2022 commercial fleet. The benefit in terms of CO_2 reduction for a sample future vehicle concept (the Blended Wing Body) is approximately 13%. The same technologies, if implemented on the projected 2022 commercial fleet, would result in a 21% reduction in CO_2 emissions for conventional transports.
- **Relevance:** This assessment provides rigorous evaluation of the CO_2 reduction benefits of the TCAT technology portfolio using the well established and documented NASA Intercenter Systems Analysis Team process. This assessment is used to determine which technologies provide the best return on investment.
- **POC:** Philip Arcara, LaRC

Technology Benefits On Future Vehicle Concepts

Using state of the art conceptual analysis tools, provide a quantitative assessment of the TCAT technology portfolio's impact on CO_2 reduction for future vehicle concepts

CO_2 Emissions

Future Vehicles

13%

CO_2 Emissions

Projected 2022 Fleet

21%

Technology	Contribution To CO_2 Reduction - BWB	Contribution To CO_2 Reduction - Conventional
Slotted Airfoil	0.64%	3.30%
Ground-To-Flight Scaling	1.77%	2.17%
Simplified High-Lift System	1.81%	1.50%
Composite Wing Structural Weight	1.41%	3.50%
Composite Wing Aspect Ratio	7.15%	7.18%
Fuel Cell APU & Power Management	0.80%	3.39%

POC: Philip Arcara, LaRC, Philip.C.Arcara@nasa.gov

Initial Intelligent Flight Control Gen-I Flight Test (3R1i)

Relevant Milestone: 3R1i - Initial Intelligent Flight Control Gen-I Flight Test

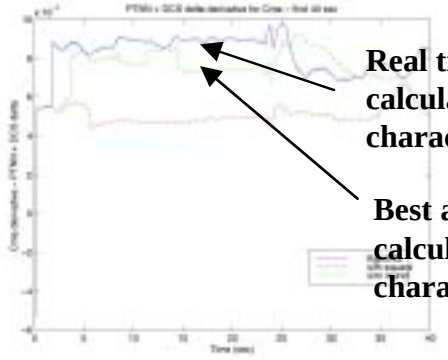
Shown: F-15 IFCS aircraft in flight obtaining real time stability derivative data. Flight data graph showing real time stability derivative calculation and Dynamic Cell Structure neural net learning. The red data are side force due to side slip stability derivative increments calculated on the aircraft during the flight. The blue trace is a time history model of the side force due to side slip increments being built by the Dynamic Cell Structure neural net in real time on the aircraft.

Accomplishment:

- First flight demonstrating real time stability derivative calculation
- First flight demonstrating Dynamic Cell Structure Neural net functioning

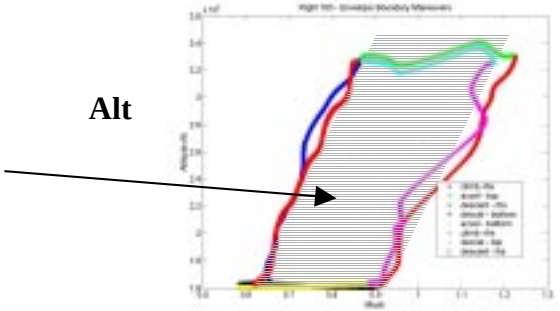
Future Plans: Flight test of second generation of intelligent flight controls, recovering from simulated in-flight failures, and providing acceptable handling qualities. Further refinement and analysis of the first generation intelligent flight controls data.

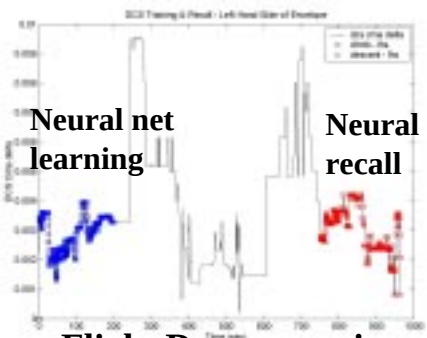
Initial Intelligent Flight Control Gen-I Flight Test (3R1i)



Real time flight characteristics calculation (Cm alpha derivative)

Flight envelope flown for IFCS data





Flight Demonstration of Dynamic Cell Structure neural net

Learning and recall

First flight test demonstrating real time flight characteristics calculation as well as a learning neural net. This software will be used in the future for learning air vehicle adaptation and failure recovery as part of Intelligent Flight Controls technology.

Initial Intelligent Flight Control Gen-I Flight Test (3R1i)

- Aeronautics Technology, VS-Advanced Vehicle Concepts, RAFV
- Target: APG3R1 - Indicator: Initial intelligent flight control generation I flight test. (First flight of IFCS Gen 1 software (NF-15) Class B, damage adaptive flight test (Drop 2)). GPRA 3R1(I)
  Metric: Demonstrate in flight real time stability derivative calculation and Dynamic Cell structure function.
- Description of activity:
  - First flight June 26, 2003
  - Results: Flight data which shows in flight stability derivative calculation and Dynamic Cell structure neural net integration of that data.
  - Availability of documentation (who/where): John Carter / Dryden Flight Research Center
- Importance of customer / How and how much it supports Enterprise (strategic plan) /benefits of technology:
  - Ames Research Center is a leading technology center for intelligent vehicle systems and on board computing technology for the nation
  - This technology directly supports the Aerospace Technology enterprise Aeronautics Technology and Space Launch Initiative themes as elements 2 and 3 of Mission I, Understand and protect our home planet. This technology also supports enabling goal 8, Ensure the provision of space access and improve it by increasing safety, reliability and affordability
  - The real time flight charactertistica calculation and Dynamic Cell Structure flight test will provide the basis for Intelligent Flight Control providing safer, more robust, and more efficient control of future vehicles

3R2a/3R5f Aligned Carbon Nanotubes for Advanced Materials

Target: APG3R5 - Select candidate technologies for experimental flight evaluation based on their impact on mobility. Mobility metrics will be measured by accessibility, doorstep-to-destination transit time, system and user costs, and related trip reliability and safety metrics. These flight experiments will evaluate individually, at the sub-system level, the impact of selected technologies on lowering required landing minimums and increasing the volume of operations at non- towered landing facilities in non-radar airspace during instrument meteorological conditions.

Indicator: Demonstrate ability to produce aligned carbon nanotubes for advanced materials (Demonstrate the fabrication of carbon nanotubes laminates.) GPRA 3R5(f), 3R2(a).

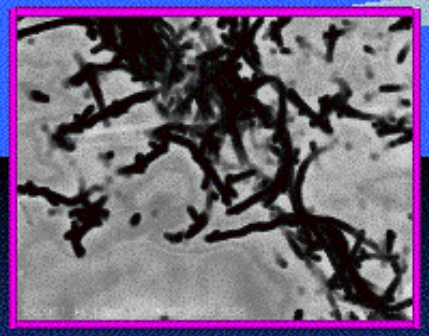
Description of activity (what was done and how): One of the significant hurdles in using carbon nanotubes is that the carbon nanotubes are difficult to disperse in the polymer matrix needed to bind them. Uniform dispersion is important to make the reinforcement as efficient possible i.e. using the minimum amount of carbon nanotubes to get the largest mechanical and electrical property enhancements. Dispersion technique was determined in FY 01. This information was used to aid in the fabrication of aligned carbon nanotube nanocomposite fibers in FY 02. FY 03 was focused on fabricating laminates using lessons learned from FY 02. Future research includes exploring various processing methods for nanocomposite fabrication and characterizing nanocomposites with higher nanotube content. The objective would be finding the most efficient way of scaling up nanocomposite fabrication to make it practical for structural applications.

Date(s) of test and also date for completion of data analysis:

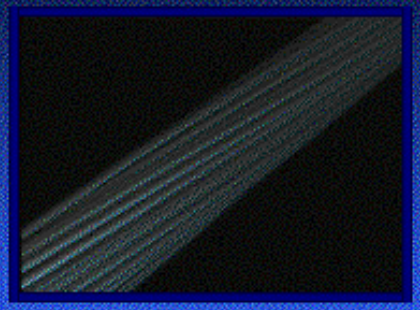
Results: In FY 03, the matrix used for the nanocomposites was switched to a material with better mechanical properties than the commercially available polyimide used in FY 02. Laminates containing 2-10% carbon nanotubes were successfully fabricated. Improvements in mechanical properties were measured. Electrical properties of these materials were also measured and significant improvement in conductivity over the baseline matrix materials was demonstrated.

Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology: Polyimide laminates with aligned CNTs have the potential for significant stiffness and strength increases over unreinforced fibers in composite structural applications. Furthermore, with improved electrical properties, the potential for a multifunctional material with improved mechanical properties and sensing capabilty can enable more efficient designs of lightweight, multifunctional airframes.

Demonstrated CNT Nanocomposite Laminate for Structural Applications



Randomly aligned Carbon Nanotube Fibers



Aligned Carbon Nanotube Fibers Demonstrated 8/02

CNT Nanocomposite Demonstrated 8/03

NASA LaRC

Morphing
Adaptive Drag Reduction Techniques

Target: APG3R2 - Reduce Emissions.

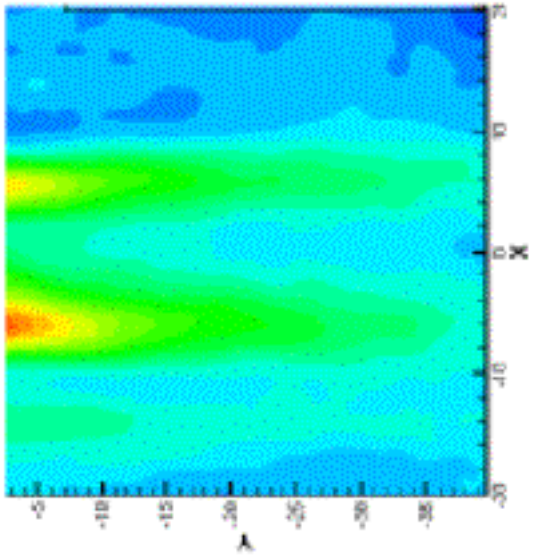
Indicator: Demonstrate adaptive drag reduction techniques. (Preliminary assessment of adaptive drag reduction techniques). GPRA 3R2(d)

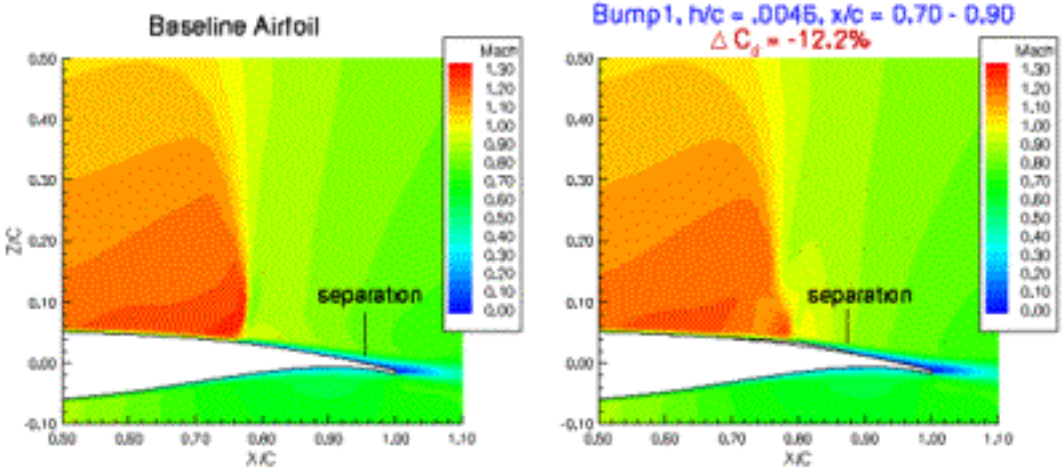
Results: Airfoil contour bump development effort has produced new aerodynamic designs that computationally show up to 12-15% drag reductions at transonic condition. A bench top demonstration model is also planned to look at implementation issues (structural/actuation/sensors)

Adaptive Drag Reduction Techniques

Preliminary Assessment

Wake of sublayer vortex generator measured by PIV





Piezoelectric Vortex Generator Flow Data

- Particle Image Velocimetry (PIV) measurements conducted with a surface mounted piezoelectric VG
- Large regions of turbulence intensity reductions downstream of VG

Shock Spreading Method

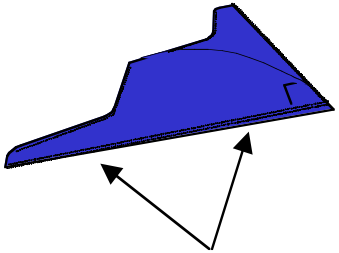
- Airfoil contour bump development effort has produced new aerodynamic designs that computationally show up to 12-15% drag reductions at transonic condition
  - WT model being fabricated for 0.3 M TCT
- "Bench top" demonstration model is also planned to look at implementation issues (structural/actuation/sensors)

Demonstrate Feasibility of Active Flow in Three-Dimensional Environments

- Target: Achieve aircraft control using embedded piezo-electric driven synthetic jets on UAV with 50° swept leading edge
- Indicator: Conduct testing of Stingray vehicle (morphing)
- Description of activity (what was done and how): Active flow control was applied to a full-scale model of an existing UAV to determine amount of vehicle control possible through distributed small-scale actuators. Arrays of piezo-electrically driven synthetic jets (zero-net mass) were integrated into the leading edge of the Stingray model in the wind tunnel.
  - Synthetic jets were driven at resonant frequency and modulated to effective frequencies for flow control.
  - Level of control from AFC same magnitude as moments generated by flaps along at high angle of attack.
  - AFC controls characteristics of 3-D separation and reattachment to modify the local time-averaged pressure distribution.
  - Over angle of attack range considered, flow separates over outer 50% of wing, or 25% of planform area. AFC in this application does not generate large changes in vehicle lift, but produces significant control authority as flaps become less effective.
  - The extent of the change in moments increases with excitation amplitude and depends on modulation frequency. The moment change levels off at higher excitation amplitudes. The most striking results is that the sign of moment sensitivity due to excitation is a function of modulation frequency.
- Importance to Customer/How and how much it supports Enterprise (strategic plan)/ benefits of technology:

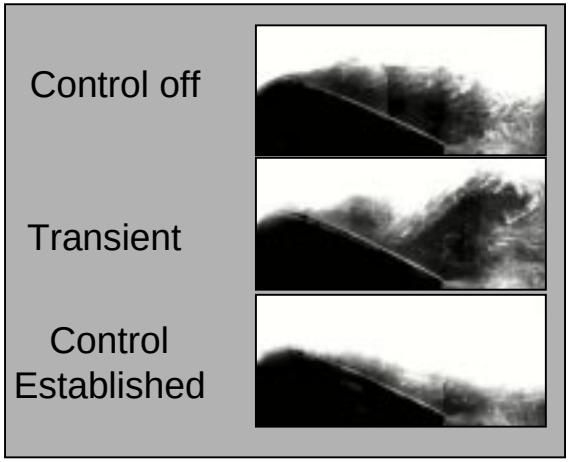
Demonstrate Feasibility of Active Flow in 3-D Environments

- Complete open loop Stingray vehicle testing
  (Completed 12/02)



Synthetic jets located on leading edge

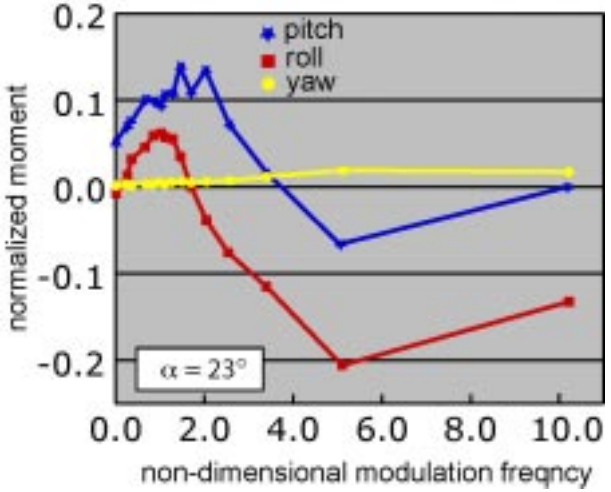
Previous 2D Physics Experiments



Georgia Institute of Technology

BOEING

Active Flow Control of vehicle moments, port jets on, δ_f = 0, 0, 0, 10°



Abrupt Wing Stall Design Guidelines
ASCOT

Target: APG3R5 - Select candidate technologies for experimental flight evaluation based on their impact on mobility. Mobility metrics will be measured by accessibility, doorstep-to-destination transit time, system and user costs, and related trip reliability and safety metrics. These flight experiments will evaluate individually, at the sub-system level, the impact of selected technologies on lowering required landing minimums and increasing the volume of operations at non- towered landing facilities in non-radar airspace during instrument meteorological conditions.

Indicator: Publish AWS validated figures of merit and design guidelines. (Abrupt wing stall design guidelines.). GPRA 3R5(h).

Description of activity (what was done and how): A series of wind-tunnel and computational studies have been conducted over a 5-year period to understand the abrupt wing stall (AWS) flow phenomenon that has historical plagued high-performance aircraft design over years. The effort was a joint NASA/DOD investment and correlations of the results were made with flight data.

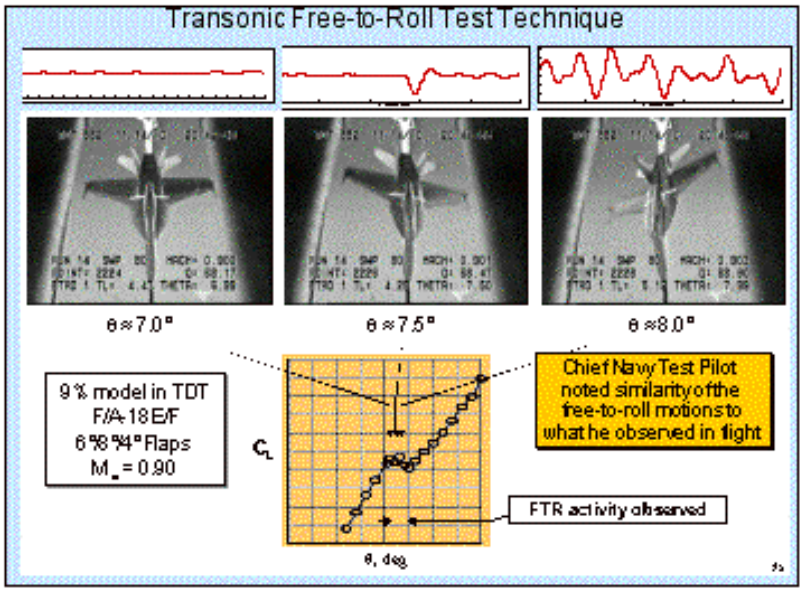
- Date(s) of test and also date for completion of data analysis: The last major wind tunnel entry was completed in the Langley 16-ft TT in June 2002. Wind-tunnel free-to-roll (FTR) data were taken on F/A-18C, AV-8B, F/A-18E, and F-16C.
- Results: Analysis shows that FTR technique is more reliable in predicting flight than historical (conventional) figures of merit, such as lift- curve breaks. Both steady and unsteady CFD investigations provided useful insight on understanding of the AWS phenomena.
- Testing limitations:

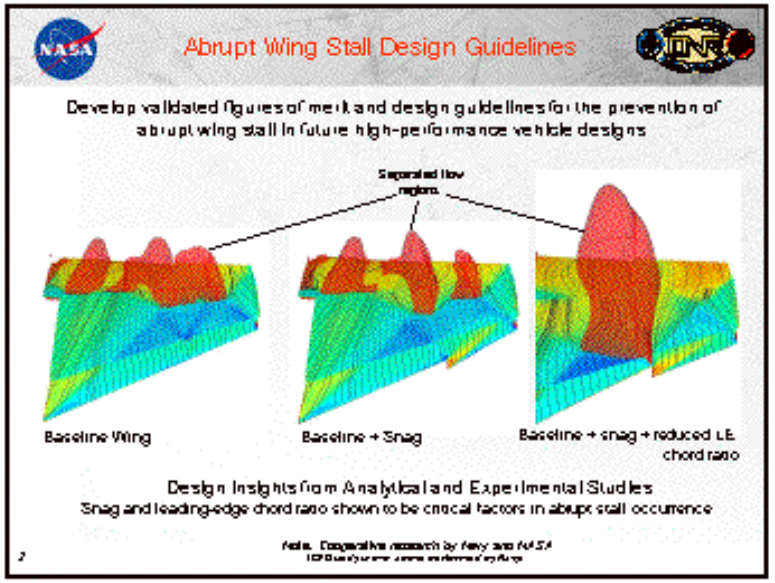
Availability of documentation (who / where): Eighteen AWS papers were presented at the AIAA Aerospace Sciences Meeting in Reno, NV. Paper by Bruce Owens et al. was selected as best paper in AIAA Applied Aerodynamics.

Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology: The AWS Team (NASA/NAVAIR personnel) briefed to the three major military airframers -- Lockheed-Martin, Boeing, and Northrop Grumman. NASA personnel participated in a JSF Review of Potential Uncommanded Lateral Motions at Lockheed Martin - Ft.Worth. AWS technology has been directly transitioned to industry as Lockheed Martin conducted a reimbursable JSF free-to-roll wind-tunnel test in the Langley 16-FT Tunnel on March 2003.

Abrupt Wing Stall (AWS) Research

AWS Figures of Merit and Design Guidelines



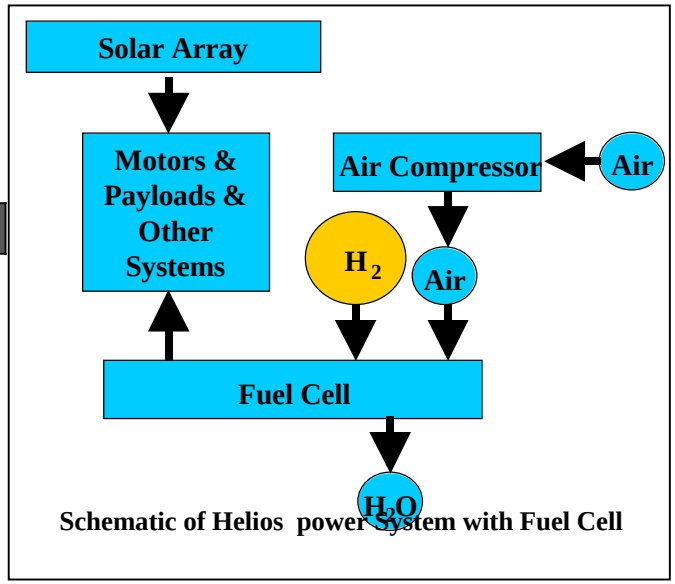


Helios – Energy Storage System

- Annual Performance Goal: Demonstrate prototype electric powered Helios aircraft by sustaining level flight for minimum of 14 hours at altitude above 50,000 feet.
- Accomplishments: Prior to the Helios loss on June 26, 2003 a number of significant challenges were overcome by the NASA/AeroVironment Team to flight test the Hydrogen Consumable Fuel Cell System.
  - Concept to flight test of an automotive hydrogen/air powered fuel cell system in 18 months.
  - The 18.6 kW fuel cell designed to operate only in ideal sea-level conditions was made to work in sub-atmospheric conditions and performance data collected.
  - A very light weight single stage compressor was developed to boost the fuel cell system pressure from atmospheric pressure (1.3 psi (@55k ft) to a pressure useable by the fuel cells.
  - Lightweight composite tanks for the 4,500psi hydrogen were developed and exceeded industry H2 gaseous mass storage efficiency standards.
  - Successfully integrated and packaged fuel cell system components.
  - Developed software and demonstrated safe operation of the overall fuel cell system.
- Relevance:Fuel cells as power system for high altitude class of vehicles may enable high altitude and long endurance missions. This technology supports NASA Mission, Goal 10.7: *Enhance NASA's mission by leveraging partnerships between NASA enterprises and non-aerospace U.S. industry firms and by leveraging the venture capital community for innovative technology development*.
- POC:John Del Frate, DFRC
- Recovery Plan: Given the loss of Helios and the end of the ERAST Program in FY03. A multi-center re-planning effort is underway to formulate a 15 year High Altitude Long Endurance (HALE) technology development project for this class of vehicles.

Helios – Energy Storage System

Integration of Hydrogen/Air Fuel Cell system into Solar powered Helios



Schematic of Helios power System with Fuel Cell

Helios aircraft 1st Flight with Hydrogen/Air Fuel Cell Pod and hydrogen tanks conducted on June 7, 2003.

Energy Systems goal was to enable Helios overnight flight capability.

Helios aircraft was lost on June 26, 2003 (Mishap). MIB report expected 1st QTR FY04.

Supersonic Natural Laminar Flow Phase II

Objective: Initial demonstration of Arizona State University distributed roughness concept to achieve laminar flow by controlling cross-flow during supersonic flight.

Status: Completed, 4Q/03

Accomplishments:
- Completed 11 flights to Mach 1.85 and a dynamic pressure of 1200 psf
  - Clean test article
  - Pressure distributions
  - Temperature map
  - Digital capture
  - Baseline distributed roughness
- Performed initial assessment and analysis.

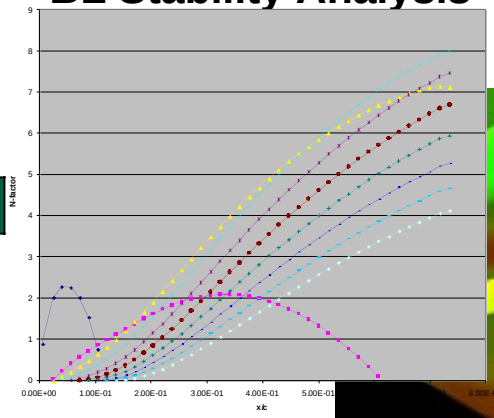
Plans:
- Milestone completed.
- Complete data analysis.
- Refine transition prediction methods.
- Perform additional ground and flight tests with updated methodology.

Significance:
- Results in flight did not compare with wind tunnel and CFD predictions. The behavior of the cross-flow instability in flight is not completely understood. Results will be used to refine the understanding and codes used to predict cross flow transition on flight vehicles.

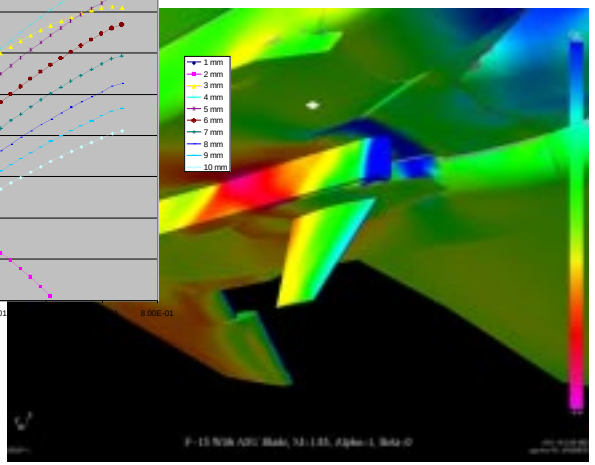
Supersonic Natural Laminar Flow Phase II

Flight Validation

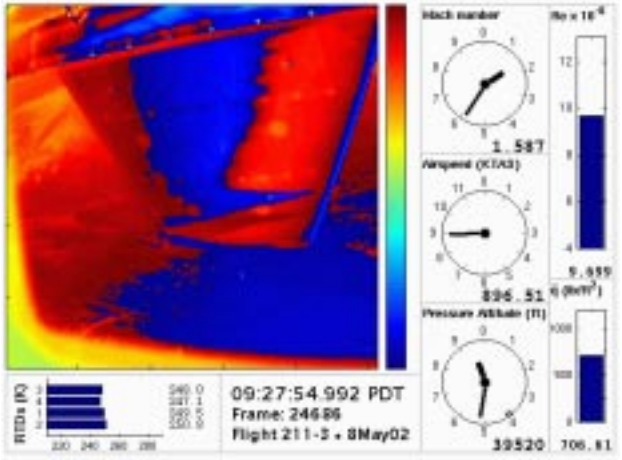
BL Stability Analysis



Wind Tunnel & CFD



Refine Methodology



Integrated Analysis

Results in ….

- **Economic Supersonic Designs**
- **More complete understanding of flow physics**
- **Better design tools**

Advanced Aeroelastic Wing Parameter Identification Flight Data

- Revolutionize Aviation, Vehicle Systems, Flight Research, Advanced Systems Concepts
- Target: 3FR03– Advanced Aeroelastic Wing Parameter Identification Flight Data
- Indicator: Dramatic improvement in accuracy over existing aerodynamic and loads models and match flight data within 10%.
- Metric: Demonstrate the operation of the AAW Flight Control throughout the AAW Flight Envelope and obtain high quality flight data that measures wing loads, flight control system parameters, and aircraft accelerations within 10%.
- Description of activity:
  - Date(s) of test and also date for completion of data analysis: November 2002 to April 15 2003.
  - Results: Demonstrated the AAW flight control system throughout the AAW experiment envelope. Obtained high quality flight data at 18 of the planned 20 test points and four intermediate points. Complete data was unobtainable at two test points due to performance limitations of the F-18 to obtain the required steady conditions.
  - Availability of documentation (who/where): Larry Myers / Dryden Flight Research Center
- Importance of customer / How and how much it supports Enterprise (strategic plan) /benefits of technology:
  - Provided initial demonstration of full scale Active Aeroelastic wing technology to meet Air Force customer requirements.
  - Provided high quality data to improve aeroelastic loads and aerodynamic modeling that will be required to meet the flexible wing structures goals of revolutionary aircraft.
  - Provides the data base to develop control laws that will exploit flexible wing technology.

Active Aeroelastic Wing (AAW) Parameter Identification (PID) Flight Data

AAW aircraft completing PID maneuver.
Notice split Leading Edge Flap (LEF).
Outboard LEF commanded up to get
Wing twist data.

Completion of first flight.
AAW PID flights started Nov 15
And finished Apr 15, 2003. 50 Flight.
Nine subsonic and nine supersonic
Test conditions.

An aircraft traveling through the atmosphere continuously produces airpressure waves similar to waves created by the bow of a ship. When the aircraft exceeds the speed of sound (approximately 750 mph at sea level), the pressure waves combine to form shock waves, which are heard as a sonic boom when they reach the ground.

The flights were conducted at the NASA Dryden Flight Research Center at Edwards Air Force Base, Calif. An F-5E aircraft with a specially modified nose section flew supersonically through the test range, and sensors on the ground and in other aircraft measured the sonic boom overpressure. Shortly thereafter, an unmodified F-5E flew supersonically through the same airspace. The data comparison of the two aircraft signatures clearly showed a reduction in intensity of the sonic boom produced by the F-5E with a modified fuselage. An identical test later in the day confirmed these results.

"The demonstration has proven the theory that you can reduce sonic boom intensity by changing aircraft shape, and engineers will be able to study the data to learn more about the effects of aircraft shaping on sonic overpressure," said Boccadoro. "Based on those studies, an experimental aircraft could eventually be built that will produce a noticeably quieter sonic boom."

The Shaped Sonic Boom Demonstration (SSBD) program is a $7 million cooperative agreement with Northrop Grumman, DARPA and NASA's Langley Research Center and Dryden Flight Research Center. Other government and industry entities are participating in the program.

The F-5E's modifications, which were designed and installed by Northrop Grumman, include a specially shaped "nose glove" and the addition of aluminum substructure and a composite skin to the underside of the fuselage. The U.S. Navy's Naval Air Systems Command provided the F-5E aircraft.

AVIATION HISTORY IN THE MAKING -- An F-5E aircraft with a modified forward section takes off Aug. 27, 2003, on a test flight that demonstrated for the first time that changing a supersonic aircraft's shape can reduce the intensity of the sonic boom it produces. A team led by Northrop Grumman Corporation, DARPA and NASA made aviation history by demonstrating this technology, which could usher in a new era of supersonic flight.

Photo Release -- Northrop Grumman/Government Team Shapes Aviation History With Sonic Boom Tests
Aircraft-Shaping Theory Proven Sound in First Flight Demonstration

EL SEGUNDO, Calif., Aug. 28, 2003:

Officials from DARPA, Northrop Grumman and NASA will discuss the results of the sonic boom demonstration at a media briefing scheduled for 9 a.m. EDT Wednesday, Sept. 3, in the First Amendment Lounge at the National Press Club, 529 14th Street NW. Media interested in attending should contact Gus Gulmert in Northrop Grumman's Washington, D.C., office at 703-875-8450 or via e-mail at gus.gulmert@ngc.com.

Northrop Grumman Corporation's (NYSE:NOC) Integrated Systems sector, in cooperation with the Defense Advanced Research Projects Agency (DARPA) and NASA, has made aviation history by demonstrating a method to reduce the bone-jarring impact of sonic booms, a technology that could usher in a new era of supersonic flight.

Photos accompanying this release are available at: http://media.primezone.com/noc/

In flights conducted Aug. 27 on the same supersonic test range where Chuck Yeager first broke the sound barrier nearly 56 years ago, the government/industry team showed that modifying an aircraft's shape can reduce the intensity of its sonic boom. This theory had never been demonstrated in actual flight.

The technology, being developed as part of DARPA's Quiet Supersonic Platform (QSP) program, could eventually lead to unrestricted supersonic flight over land.

"During this centennial year of manned flight, Northrop Grumman has demonstrated once again that it remains on the cutting edge of technical innovation," said Charles Boccadoro, Northrop Grumman's QSP program manager. "This theory had been demonstrated only in laboratories and wind tunnels. It took a cooperative effort of government and industry to achieve this breakthrough."

SIDE-BY-SIDE COMPARISON -- These two F-5E aircraft were part of aviation history on Aug. 27, 2003, when they helped demonstrate for the first time that changing a supersonic aircraft's shape can reduce the intensity of the sonic boom it produces. The forward section of the aircraft on the right was modified for the tests, and its sonic boom was compared to the boom produced by the unmodified F-5E on the left.

Northrop Grumman's SSBD team includes Wyle Laboratories, El Segundo, and Eagle Aeronautics, Hampton, Va. Also participating in the SSBD program are General Electric Co., Lockheed Martin Corp. and The Boeing Co. General Electric provided technical assistance with the aircraft engines, Lockheed Martin supplied ground-based sensors and Boeing provided a T-38 chase aircraft for the initial F-5E envelope expansion flights.

DARPA's QSP program is an effort to identify and mature technologies that could allow military and business aircraft to operate with reduced sonic boom. Northrop Grumman Integrated Systems has been working under contract with the QSP program since 2000 at its Advanced Systems Development Center in El Segundo. As part of that work, the company has designed a long-range supersonic military aircraft and validated key integration technologies associated with that design.

Northrop Grumman Integrated Systems, based in El Segundo, is a premier aerospace and defense systems integration enterprise. As one of Northrop Grumman Corporation's seven sectors, it designs, develops, produces and supports networkenabled integrated systems and subsystems for U.S. government, civil and international customers. Integrated Systems delivers best-value solutions, products and services that support military missions in the areas of intelligence, surveillance and reconnaissance; battle management command and control; and integrated strike warfare.

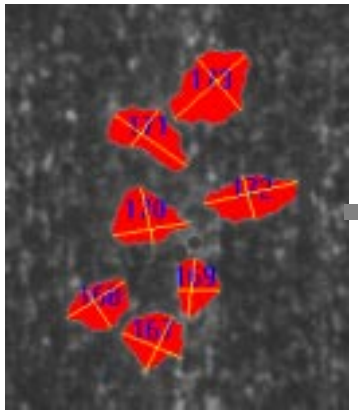
Members of the news media may receive our releases via e-mail by registering at:
http://www.northropgrumman.com/cgibin/regist_form.cgi

LEARN MORE ABOUT US: Northrop Grumman news releases, product information, photos and video clips are available on the Internet at: http://www.northropgrumman.com. Information specific to the Integrated Systems sector is available at: www.is.northropgrumman.com/index.html

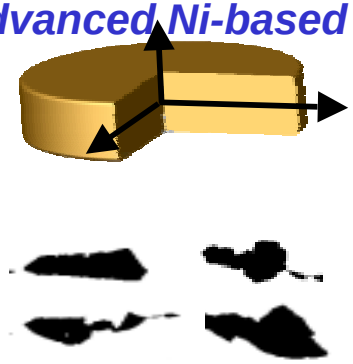
Nickle-Based Turbine Disk Superalloys
USP

- Target: APG3R1 - Demonstrate progress in maturing, through flight tests and/or simulations, the critical technologies that will be necessary to meet the aviation safety objective. These tests and simulations are critical steps in the development of a suite of technologies that when completely developed and implemented by the customer, will provide a minimum of 50 percent reduction in fatal accident rate.
- Indicator: Validate life prediction methodology for critical powder metallurgy superalloy engine components (nickel-based turbine disk) to enhance aircraft safety (Develop reliable life prediction concepts for advanced Ni-based turbine disk superalloys.). GPRA 3R1(h).
- Metric:
- Description of activity (what was done and how): Probabilistic Life Prediction Methodology has been developed for powder metallurgy nickel based superalloys for high and medium stran ranges. The methododogy accounts for the presence of ceramic inclusions in the components and predicts lives of the component based on the input distributions of inclusion densities, size and shape. Milestone requirements for experimental testing and analysis have been completed for high and medium strain conditions.
  - Date(s) of test and also date for completion of data analysis:
  - Results: Milestone has been accomplished and the technology will transition to the Aviation Safety and Security Program for further development.
  - Testing limitations: The newly-developed probabilistic life prediction methodology has been shown to accurately predict the fatigue life for medium and high strain ranges for both Type I and Type II ceramic inclusions. Further development of the methodology for the low strain range will be done under the Aviation Safety and Security Program.
  - Availability of documentation (who / where): Susan Johnson, Glenn Research Center
- Importance to customer / How and how much it supports Enterprise (strategic plan) / benefits of technology:
  - This newly-developed probabilistic life prediction methodology is expected to signficantly enhance the accurate prediction of the service life of turbine engine components. The methodology offers a state-of-the-art non-conservative approach to address powder cleanliness issues related to disk safety during operation. Other benefits include a potential for accurately and reliably predicting maintenance and replacement schedules for turbine disks. Our newly developed stereological algorithms incorporated into this methodology have enhanced the model's realism and increased its accuracy. Potential customers for this technology are the FAA, Southwest Research Institute, General Electric Aircraft Engines, Pratt & Whitney, Honeywell, Williams International and Rolls Royce.
- Recovery plan (if not successful) - N/A

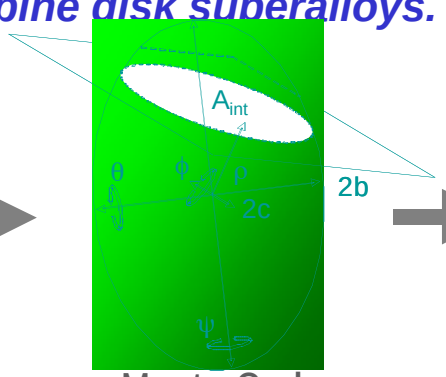
State of the art probabilistic fatigue model developed for advanced Ni-based turbine disk superalloys.



Seed Analysis

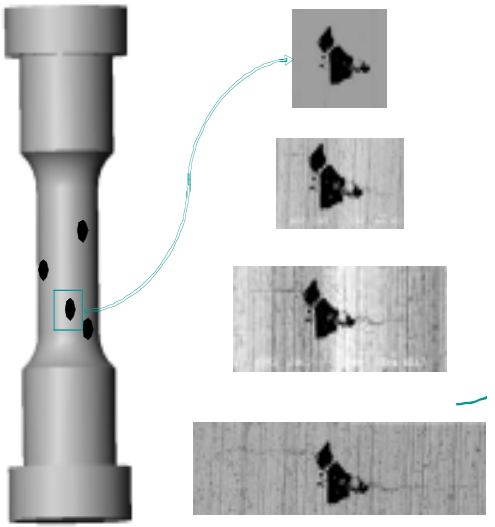


Forging Characterization

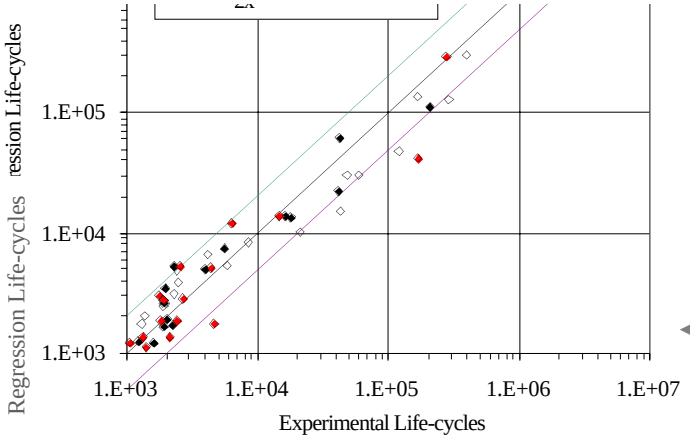


Monte Carlo Simulation

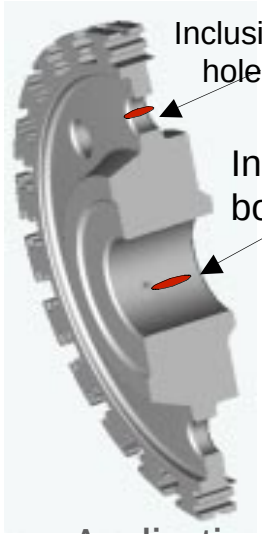
LCF Testing



Interrupted Crack growth testing



Model Formulation



Application

Model incorporates the effects of processing on inclusion morphology to accurately predict fatigue life.

Engine Test a Coated PMC Inlet Guide Vane

Project: Higher Operating Temperature Propulsion Components – HOTPC

Status: Completed, 1Q/03

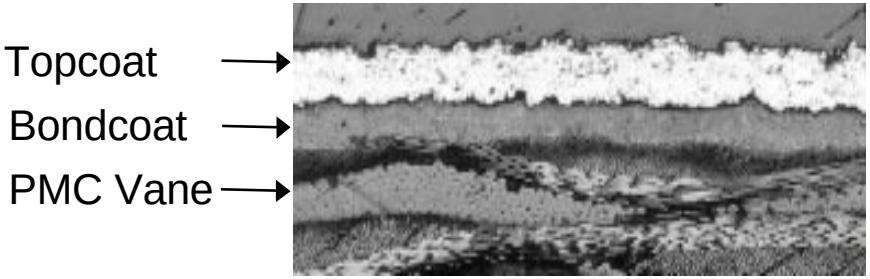
Accomplishment:
- The University of Cincinnati tested erosion samples which have been optically measured, IH, to determine coating performance. Laser interferometer scanning was conducted on 18 randomly selected pre-tested specimens as well as the remaining 50+ samples.
- All shaker tests have been completed, IH. NDE has been conducted on all specimens.
- A video has been produced to capture the process that Engelhard, Inc. employed to deposit the coatings unto the PMC components. This tool can now be utilized as an instruction guide for future customers.
- Coating has extended the erosion life of the PMC inlet guide vanes by 2-3 times.

Plans:
- Milestone completed.

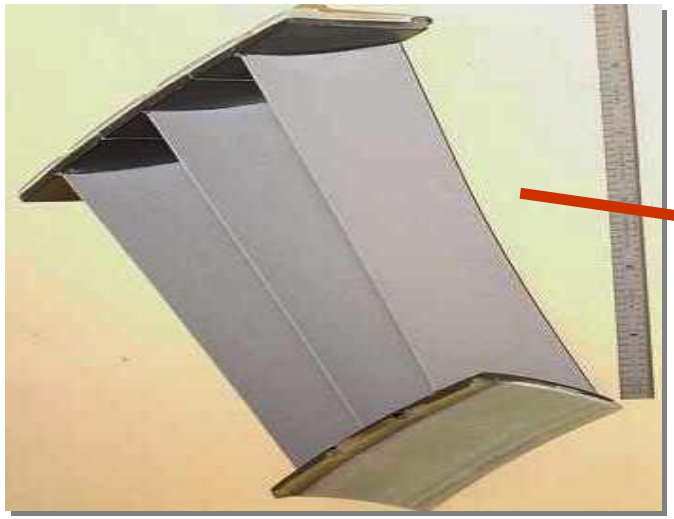
Significance:
- The successful lab and engine test demonstration of the erosion resistant coating developed in this GRC project is a critical pre-cursor to implementation into Rolls-Royce Indianapolis AE3007 engine production where a significant extension of the erosion life of the 72 polymer matrix composite fan inlet guide vanes is expected.

Erosion Resistant Coatings for PMC Structures

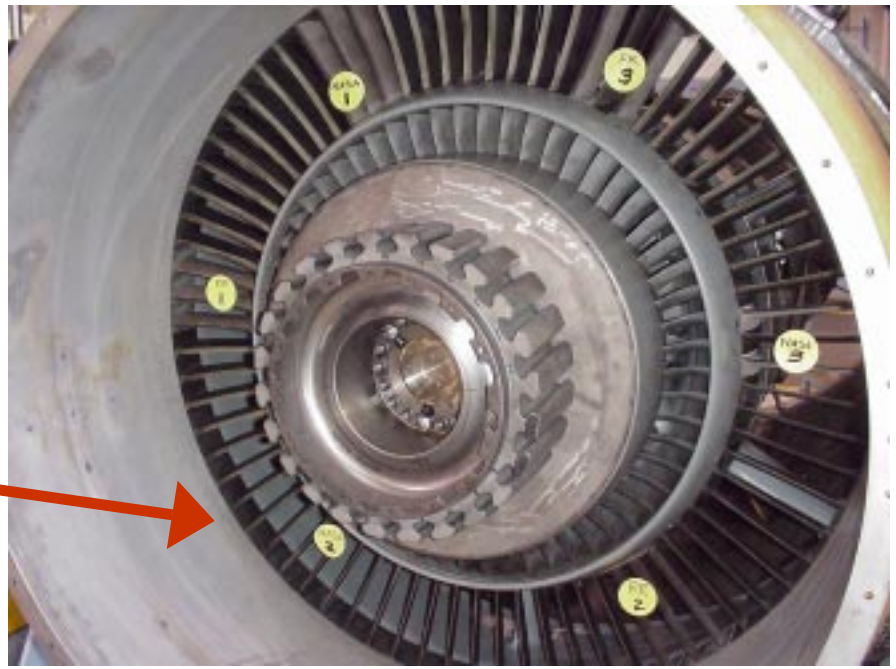
NASA's Coating Increased the Durability of the Component by a Factor of more than 2X



Coating Process Defined



Coating Applied to PMC Vanes



Coated Vanes Inserted into AE3007 1000 Hour Engine Test Which Began August, 2002